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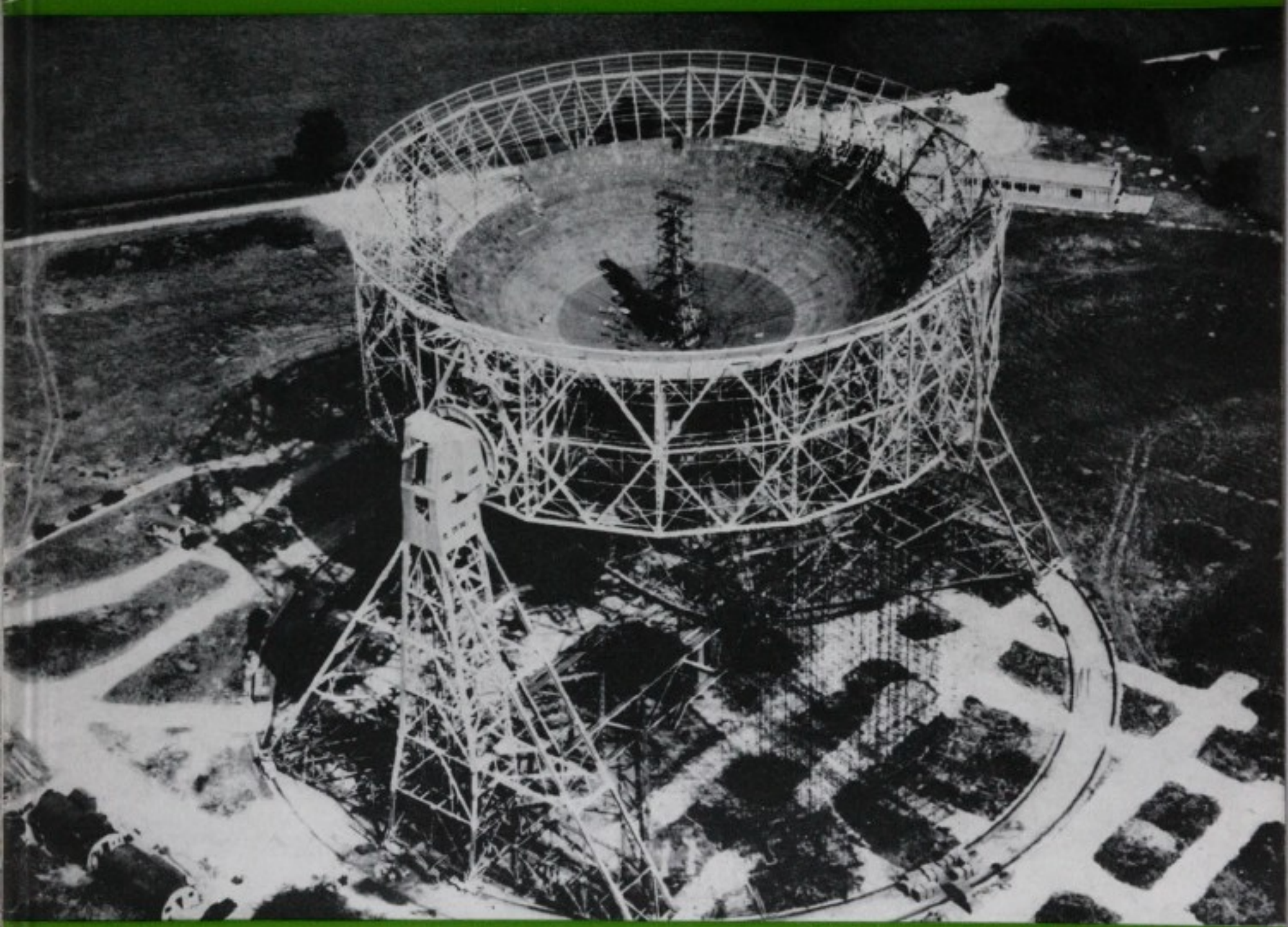

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SEPTEMBER, 1957

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Vol. XVI, No. 11 SEPTEMBER, 1957

CONTENTS

COVER: The 250-foot radio telescope at the Jodrell Bank Experimental Station of the University of Manchester, England, in a late stage of construction. In the foreground is seen the double circular track for rotation of the entire instrument in azimuth. Above center is the huge paraboloidal reflector, its interior partly covered with reflecting material. The dish is supported horizontally by trunnions on very tall supporting towers, one conspicuous at the left of center in this picture. Inside the dish, scaffolding surrounds the central column that holds the receiving antenna at the focus of the paraboloid. Beyond the telescope, in upper right, a portion of the administration building appears. British Information Services photograph. (See page 516.)

ENGLAND'S GREAT RADIO TELESCOPE 516

A SURVEY OF BRIGHT SOUTHERN GALAXIES
— Gerard de Vaucouleurs 520

A PROBABLE METEORITE CRATER OF GREAT AGE
— C. S. Beals 526

AMERICAN ASTRONOMERS REPORT 529

STELLAR SPECTROGRAPHS — I — Otto Struve 536

AMATEUR ASTRONOMERS 534
Middle East Convention Held in Harrisburg
Philadelphia MOONWATCH

BOOKS AND THE SKY 542
Vistas in Astronomy — Volume 2

GLEANINGS FOR ATM's 548
A Wide-Field Telescope with Spherical Optics
How Little Abrasive?

HERE AND THERE WITH AMATEURS 532

LETTERS 518

NEWS NOTES 519

OBSERVER'S PAGE 555
Northern Lights Usher in the IGY
Deep-Sky Wonders

QUESTIONS 518

STARS FOR SEPTEMBER 561

FEATURE PICTURE: A region in the constellation of Orion as recorded on a photograph in red light taken with the 48-inch Schmidt telescope. Mount Wilson and Palomar Observatories photograph. 531

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EXPERIMENTS SIMULATE GROWTH CONDITIONS ON MARS

Evidence that life can exist on Mars, obtained by allowing bacteria to reproduce under conditions similar to those on the ruddy planet, was presented at the joint meeting of the Astronomical Society of the Pacific and the International Mars Committee at Lowell Observatory in June. The eight-month research project was conducted by Lt. J. A. Kooistra, Jr., at the Air Force School of Aviation Medicine, Randolph Air Force Base, Texas, under the supervision of Drs. R. B. Mitchell and Hubertus Strughold.

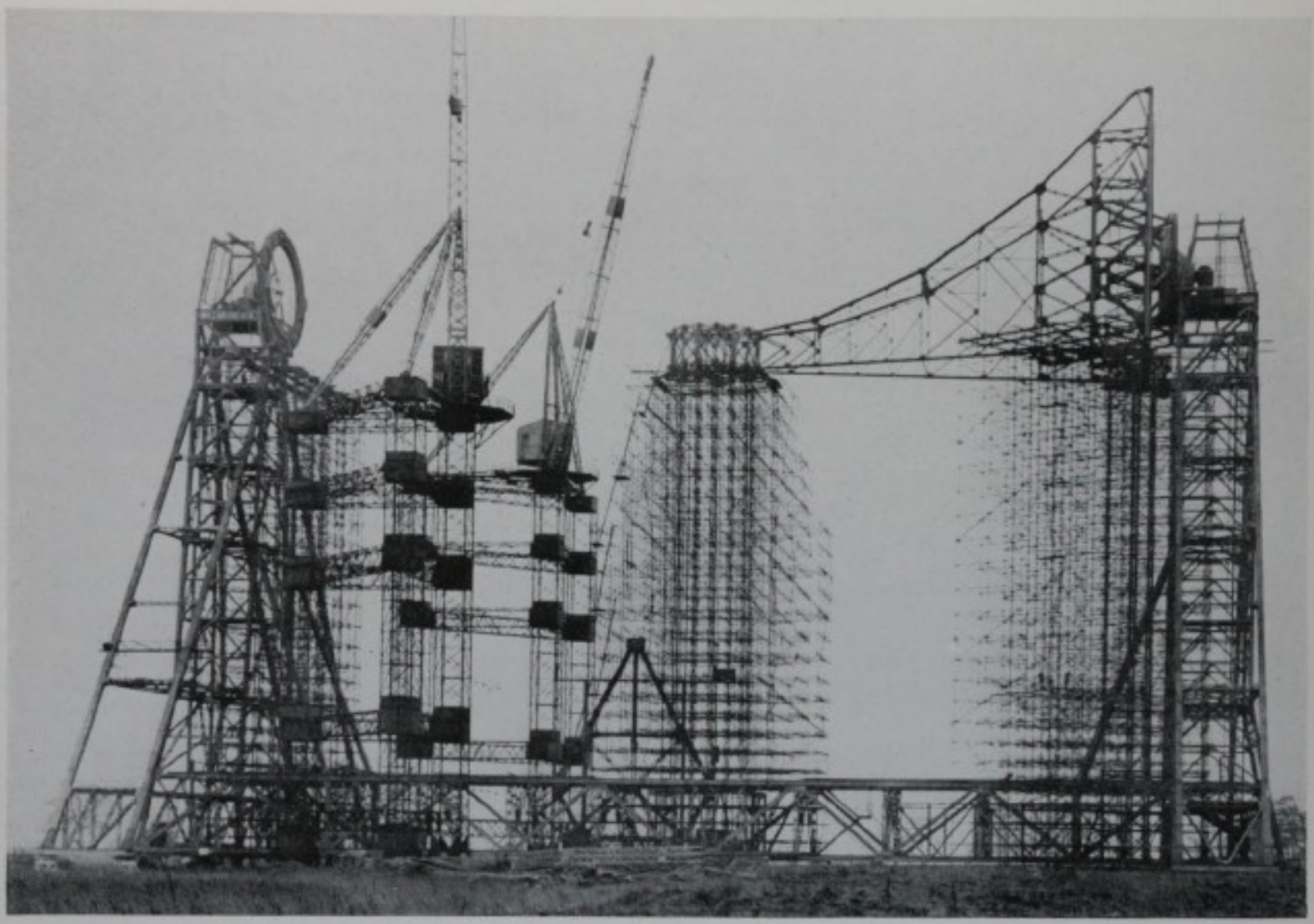
Soil samples were procured from desolate regions of the United States, including McGonagal Pass on Mt. McKinley in Alaska, the Grand Canyon, and the Painted Desert in Arizona; pulverized red sandstone from the last of these places superficially resembles the surface of Mars. Nitrogen-loving bacteria, already "at home" in such arid areas, were put in the jars with the soil samples. The air was replaced with pure dry nitrogen, and the bacteria had to live on the trace of moisture and the organic materials contained in the soil.

The surface temperature of Mars ranges from a maximum of 70° Fahrenheit, at noon on a summer day in the tropics, to as low as 95° below zero on a winter night. Since Mars' day is not much longer than a day on the earth, the experimenters found it a simple matter to reproduce Martian temperature changes, placing the jars in freezer compartments overnight and letting them warm up to room temperature by day. The bacteria multiplied in the warmth of the day; most of them survived the cold at night.

When the soil moisture content was more than one per cent, the population of bacteria increased, but it declined if the moisture was less than this percentage. Certain numbers of them, however, survived and were able to reproduce in a moisture content of only two-fifths of one per cent. Further experiments are under way to determine whether these hardier specimens can survive with even less moisture in the ground.

ROCKET SETS RECORD

On April 30th an Aerobee-Hi rocket reached an altitude of 193 miles, bettering the previous world record for a single-stage rocket by 29 miles. The missile attained 4,900 miles an hour during its flight and landed 50 miles north of the launching site at White Sands Proving Ground, New Mexico, according to a report in the June issue of *Jet Propulsion*. The burnout time was 53 seconds, the rocket then being at an altitude of 147,000 feet, with a speed of 7,200 feet per second.



An early stage in the construction of the 250-foot radio telescope is shown here. One of the altitude-pivot bearings is only partly in place at the top of the left-hand tower. Between the right-hand tower and the central pedestal the first frame members of the paraboloidal reflector have been assembled. All photographs with this article are from the British Information Services.

England's Great Radio Telescope

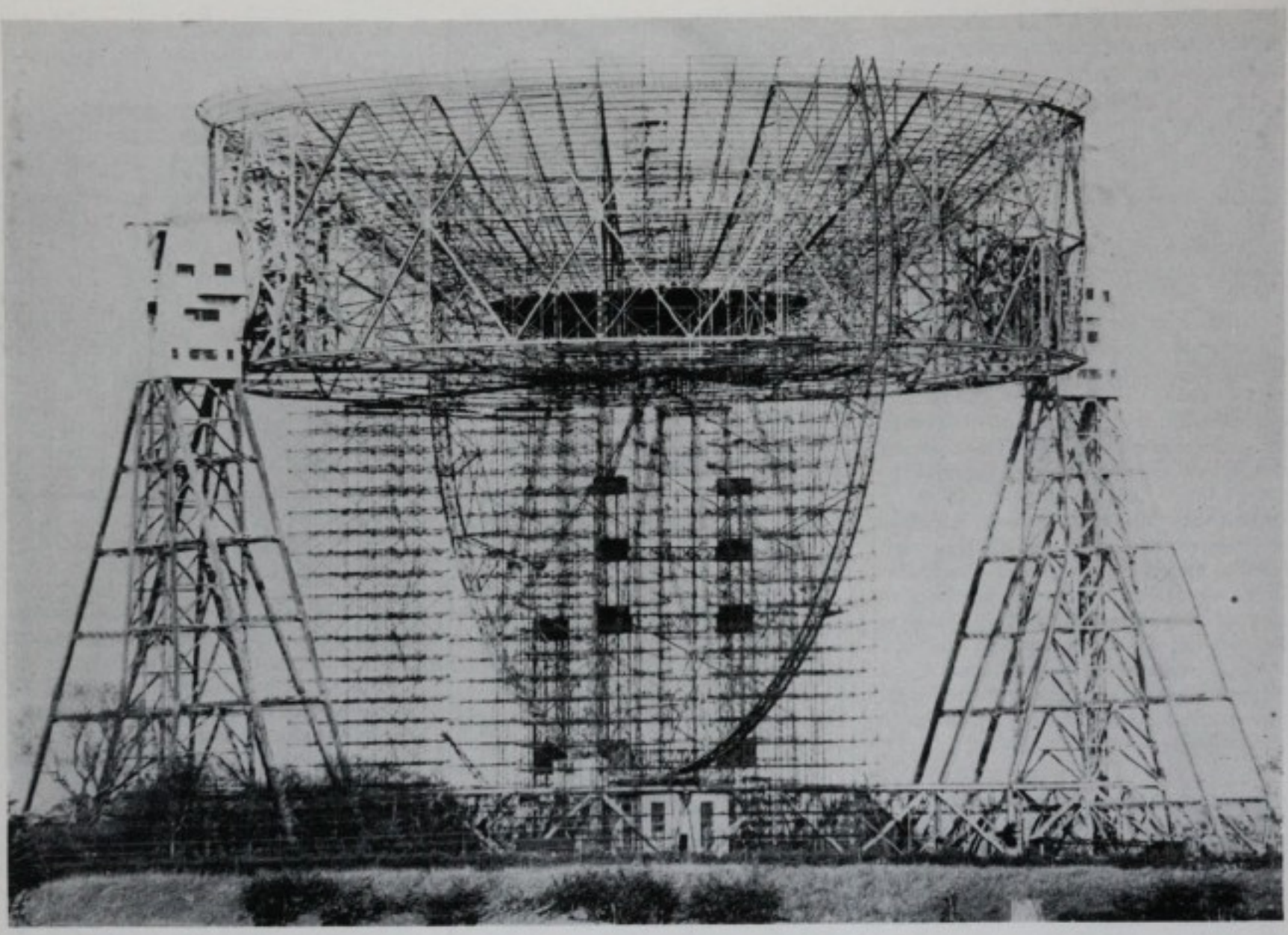
ONE HUNDRED years ago, British astronomers were making and using the world's largest telescopes, including the "Leviathan of Parsonstown," the 72-inch reflector of the Earl of Rosse. But the weather of the British Isles constantly interfered with large-aperture observing, and new great telescopes were erected at more favorable observing sites in other parts of the world.

The largest optical telescopes are located in the United States, Canada, South Africa, and Australia, where better skies prevail, on the average, than in Great Britain. Now, however, with the advent of radio astronomy, which can be carried on when it is cloudy, leadership in construction of giant radio telescopes has been assumed by the British.

If a telescope is in general required to be an instrument that can be pointed to any part of the heavens, then the world's largest radio telescope is by far the 250-foot paraboloidal reflector at the Jodrell Bank Experimental Station of the University of Manchester. This huge device, pictured on the front cover, is now being completed at an estimated total cost of more than two million dollars, just in time to participate in the British program of the International Geophysical Year.

The radio astronomy program at Jodrell Bank was described by its director, Dr. A. C. B. Lovell, in *Sky and Telescope* for February and March, 1953, when the foundations for the 250-foot telescope were being placed. Since then the tremendous construction task has been pursued with vigor, but it was complicated by the decision to change the original design so the paraboloid could collect and focus waves as short as 10 centimeters. Thus the telescope will now be able to observe galactic and extragalactic radio energy at 21 centimeters, emitted by atoms of neutral hydrogen in their lowest energy states. The 21-cm. line has proved to be a powerful probe of the Milky Way galaxy, giving important information concerning its structure and rotation. The new wave-length range of the 250-foot is from 10 centimeters to about 20 meters.

This change to include shorter wave lengths required that the reflector have a higher surface accuracy than could be easily obtained by stretching wire mesh over the skeleton framework. The surface of the bowl is now formed of welded plates of bent mild steel, $\frac{1}{8}$-inch thick, a material that has a highly satisfactory degree of electrical conductivity. It forms a continuous shield against extraneous radiations from behind the direction in which the telescope is pointing, an important consideration because man-made radio interference is not at a minimum in the Jodrell Bank area. The steel will be suitably painted to prevent a serious concentration of heat at the focus during observations of the sun.



Compare this view with the one on the facing page. Now the framework of the paraboloid is completed, and some of the plates that will cover its surface are already placed in the center. The circular supporting member for motion in altitude is completely formed, and the walls of the laboratories at the tops of the towers are erected. This picture was taken some time before those on the next page and the front cover.

Four principal problems had to be solved by the telescope's designer, H. C. Husband, of Sheffield, England. The paraboloidal reflector must keep its shape during rotation and under the effects of wind and temperature; the driving system has to be strong enough to overcome any foreseeable wind condition; the automatic controls must drive the telescope at the sidereal rate, yet be variable for scanning selected areas of the sky and for tracking fast-moving objects; and the design had to be practicable from the fabrication and assembly standpoint.

All-steel construction was favored from the start because of steel's stress strength and elasticity. The weight of this metal adds to the stability of the entire instrument in high winds or sudden gusts. Steel actually has the greatest structural strength per unit cost of any metal.

Before the Jodrell Bank project began there was no data available concerning wind pressures on a bowl of steel as large as a city block. Therefore, experimental work on this phase of the design was carried out in a wind tunnel at the National Physical Laboratory at Teddington, near London. The extra steel used to face the parabola and the addition of a stabilizing member now have the advantageous effect of lowering the center of gravity of the whole structure by several feet.

In spite of the great energy-gathering power of the parabola, the amount of radiation concentrated on the aerial at the focus during celestial observations will be extremely small. In order to avoid energy losses, the actual receiving and amplifying apparatus should be as close to the aerial as possible. For some purposes the first amplifier will be adjacent to the aerial, which is at the summit of a 66-foot tower inside the bowl, but the main amplifiers are suspended in a steel laboratory hung immediately below the center of the bowl itself.

This laboratory is suspended on trunnions in order to keep its floor level while the parabola turns at various angles to the horizontal. Damping devices will prevent uncomfortable oscillations during periods of high wind. The suspended laboratory can be reached by gangways from the top of each of the two 185-foot towers that carry the horizontal supports of the paraboloid. Each of these towers itself contains a high-level laboratory, reached from the ground by passenger elevator.

The mounting of the telescope is of the altazimuth type. The paraboloid can be turned a full 360 degrees in altitude around trunnions in the towers, these containing spherically mounted split roller bearings. The paraboloid weighs more than 750 tons, and each bearing can carry a combined dead load and wind load of about 1,000 tons with a minimum of frictional resistance. When the paraboloid is inverted, it forms the largest domed roof in the world, according to the British Information Services.

The towers, in turn, stand on 12 trucks that travel on a circular track, made of specially hardened rails to withstand the 2,000-ton weight of the telescope's moving parts. Each of the 48 truck rollers runs on two rails and is slightly conical to compensate for the different radii of the tracks. The telescope is driven around its vertical axis by electric motors geared to 16 of the rollers; this provides the motion in azimuth.

An underground tunnel connects a ring-shaped chamber around the central pivot of the telescope to the administration building and control room 200 yards away. This tunnel is large enough to be walked through, and carries racks on

which power, control, and radio cables are laid. Although a maintenance crew is required for the instrument as a whole, it is possible for a single observer to direct the telescope completely from the control room. He looks out onto the entire installation, which can be illuminated at night by floodlights.

The continuously variable motions of the telescope on its two axes are achieved by generator sets situated in a substation that rotates with the instrument, immediately over the central pivot. Supplying variable amounts of electricity to the driving motors, these generators are controlled from the combined mechanical and electrical computor system located in the main control building. The tracking and scanning systems are accurate to within 12 minutes of arc.

While the Jodrell Bank radio telescope is primarily designed to study distant celestial objects, it will also have wide application in other parts of radio astronomy. Radar principles can be applied to observations of the moon and meteors, and it is reported that the 250-foot giant may be used to detect radio energy from the artificial satellite, an object only 20 inches in diameter.

QUESTIONS... FROM THE S+T MAILBAG

Q. Why don't the signs of the zodiac match the constellations in the sky?

A. Precession of the equinoxes has caused the signs to shift about 30 degrees, the width of one whole sign, in the past 2,000 years.

Q. Is there somewhere I can find a list of the positions for all Messier and NGC objects?

A. These are available in the book, *New General Catalogue of Nebulae and Clusters of Stars*, by J. L. E. Dreyer, priced at £3 10s, from the Royal Astronomical Society, Burlington House, London W. 1, England. The same volume also contains the two *Index Catalogues* that supplement the NGC.

Q. Would the navigator of a spaceship in the solar system have to worry about the sun's gravity?

A. Yes, he must take solar attraction into account, as well as the gravitational pull of any planet the ship may be near.

The radio telescope is viewed here from the control console, where scientists are installing electronic equipment. Near top center, note the tiny figure of a workman on the reflector framework.

Q. Please list some bright stars with spectra like the sun's, and give their positions and distances.

A. For each of the following five stars are given its name, visual magnitude, spectral type, right ascension and declination for 1960, and distance in light-years: Beta Hydri, 2.8, G1 IV, $0^h\ 23^m.7$, $-77°\ 29'$, 21. Eta Cassiopeiae A, 3.5, G0 V, $0^h\ 46^m.7$, $+57°\ 36'$, 18. Eta Bootis, 2.7, G0 IV, $13^h\ 52^m.8$, $+18°\ 36'$, 32. Alpha Centauri A, 0.0, G2 V, $14^h\ 36^m.9$, $-60°\ 40'$, 4.4. Zeta Herculis AB, 2.8, G0 IV, $16^h\ 39^m.8$, $+31°\ 40'$, 30.

These data are taken from the 1957 *Handbook* of the Royal Astronomical Society of Canada, where the sun's spectral type is listed as G2 V. W. E. S.

LETTERS

Sir:

In the well-known book by Russell, Dugan and Stewart, *Astronomy* (page 350), it is pointed out that when many asteroids had been discovered the supply of classical names for them became practically exhausted. Astronomers therefore commemorated not only cities, colleges, and friends, but even ocean steamers, pet dogs, and favorite desserts!

The asteroid 518 Halawe is apparently one named after a favorite dessert. It was discovered on October 20, 1903, by R. S. Dugan at Königstuhl. Before going to Germany, Dugan had worked here in Beirut, when this observatory was part of the Syrian Protestant College, and evidently he developed a taste for an Arabic sweet, *halawe*, made from sugar and sesame seed.

At the beginning of this century, Max Wolf, A. Kopff, P. Götz, and Dugan discovered several hundred asteroids, using at Königstuhl the newly developed photographic methods of Wolf. Among Dugan's minor planets are 503 Evelyn, 506 Marion, 510 Maybella, 511 Davida, 517 Edith, 519 Sylvania, 521 Brixia, 523 Ada, and 533 Sara, presumably mostly in the friend or pet category. Others he named after colleges: 508 Princetonia, 516 Amherstia, and 534 Nassovia.

Can some reader tell which asteroid was named after an ocean steamer?

OWEN GINGERICH
American University Observatory
Beirut, Lebanon

Sir:

In reference to the final question on page 326, May issue, about William H. Pickering's *Photographic Atlas of the Moon*, I have a copy in fair condition, although the binding is commencing to break.

The book was purchased in 1940 second-hand for $4.50, and it weighs four pounds. I am ready to dispose of it to an interested reader.

LAWRENCE N. UPJOHN
1556 Long Rd.
Kalamazoo 41, Mich.

NEWS NOTES

CAPE OBSERVATORY ATLAS OF SOUTHERN GALAXIES

Completion of the first part of the Cape Photographic Atlas of Southern Galaxies has been announced by the Royal Cape Observatory in South Africa. The plates for the atlas are being taken by observatory staff members with the 74-inch reflector of the Radcliffe Observatory at Pretoria, one of the two largest telescopes in the Southern Hemisphere.

Each print in the atlas measures 10 by 12 inches, the reproduction scale varying from about five to two seconds of arc per millimeter. The prints are mounted on cardboard, and on the back of each mounting are photographic exposure data and descriptive notes by David S. Evans.

Atlas subjects are chosen for their scientific, structural, or pictorial interest; in each case only the best-quality plates are selected for reproduction, several hundred actual photographs being required to obtain two dozen that meet the high standards of the project. In certain cases, prints of the same galaxy in several different spectral regions are included.

Southern objects included in the first set of 24 prints are NGC 253, 300, 434, 613, 986, 1079, 1097, 1313, 1316, 1365, 1515, 1808, 2427, 4835, 5236, 6221, 6769, 6872, 7098, and IC 5152. It is expected that further sets will be made up according to demand.

The first set, which is priced at £15, may be purchased directly from the Royal Observatory, Observatory, Cape Province, South Africa. Sample sets are available for inspection by astronomers at the offices of *Sky and Telescope* in Cambridge, Massachusetts; at the Royal Astronomical Society in London, England; and at the University Observatory, Leiden, Netherlands.

SOLAR FURNACES

There are now 26 solar furnaces either operating or under construction in the United States, according to T. S. Laszlo, in the April-July, 1957, issue of the *Journal of Solar Energy Science and Engineering* (see April issue of *Sky and Telescope*, page 271). As recently as 1954 there were only two in this country.

In 12 of the 17 furnaces surveyed by R. K. Cohen and N. K. Hiester in the same issue of the *Journal*, a 60-inch parabolic mirror is used as the concentrator, emphasizing the fact that much of the solar-furnace construction was undertaken within the past few years when surplus military searchlights were an inexpensive source of such reflectors. The maximum temperature thus far obtained by one of these 17 furnaces is 3,500° centigrade, with the 60-inch installation at Fordham University.

The solar furnace at Montlouis in France is one of the best known in the world. Problems encountered in focusing solar energy, and in building a new 1,000-kilowatt unit there, are discussed by F. Trombe.

In another article of special interest, on a subject already familiar to telescope makers and laboratory technicians, P. B. Archibald describes how paraboloidal reflectors may be produced by revolving a horizontal pan of liquid plastic and allowing it to harden into shape. Without polishing, such a surface can now be plated to make a reflector of a quality suited to various laboratory and industrial applications.

OREGON PLANETARIUM

Planetarium demonstrations at the Oregon Museum of Science and Industry, Portland, Oregon, were discontinued on May 30th, as the institution's building was to be torn down. Late in July, the museum moved to another location, at 4015 S.W. Canyon Rd., but a complete new planetarium is still in the planning stage.

Meanwhile, Director D. P. Huegli is attempting to set up the Spitz projector for temporary operation in the basement of the new building. He reports that in 1956 the planetarium had 6,000 visitors, and in the first five months of this year some 13,000 persons attended the demonstrations.

TWO ASTRONOMERS RETIRE IN CALIFORNIA

Milton L. Humason, whose observations have provided most of the evidence supporting the theory of the expanding universe, and Seth B. Nicholson, authority on solar phenomena and the discoverer of four of Jupiter's satellites, retired from the staff of Mount Wilson and Palomar Observatories in July.

Dr. Humason, who first joined Mount Wilson Observatory as a caretaker in 1917, was promoted to its staff of investigators in 1922 when he displayed observing skill as a night assistant. In the course of this work he became proficient in the photography of spectra of very faint objects. Following the discovery by Edwin Hubble in the 1920's of the major role played by extragalactic nebulae in the structure of the universe, Dr. Humason began an intense effort to record the spectra of a substantial number of galaxies over a wide range of distances. The relationship between the radial velocities measured on these spectrograms and the distances of the galaxies has had very far-reaching influence.

Dr. Nicholson discovered the ninth satellite of Jupiter in 1914, while at Lick Observatory. With the 100-inch telescope at Mount Wilson Observatory, whose staff he joined in 1915, he later found the 10th, 11th, and 12th satellites, and determined the positions necessary to fix their orbits. He collaborated with Edison Pettit in developing a very sensitive vacuum thermocouple for measuring radiation and surface temperatures of the moon, planets, and stars. Perhaps the largest part of Dr. Nicholson's work during 42 years at Mount Wilson and Palomar has concerned the sun. He has supervised the systematic collection of data on sunspots, including their magnetic polarities and field strengths, and has made detailed investigations of the correlations between solar and terrestrial phenomena.

NEAREST ECLIPSING STAR?

A 9th-magnitude star in the constellation Eridanus may be the nearest eclipsing binary star, according to David S. Evans, of the Royal Cape Observatory, in the March issue of the *Monthly Notes* of the Astronomical Society of Southern Africa.

Nine spectrum plates for the radial velocity of this star, HD 16157, show a range of at least 55 kilometers per second. The spectrum is about type *K5*, but emission lines of hydrogen and calcium appear.

Photometric observations at the Cape Observatory show the star to vary in brightness by 0.20 magnitude, with eclipses occurring at regular intervals of 1.5609 days.

At a distance of about 40 light-years, HD 16157 may be about five light-years closer to the solar system than is Castor C, previously the nearest known eclipsing binary. Relatively few eclipsing systems of this description, with faint dwarf components, are known, but they are difficult to discover.

IN THE CURRENT JOURNALS

STELLAR ASSOCIATIONS, by R. M. Petrie, *Journal* of the Royal Astronomical Society of Canada, June, 1957. "The fact that we see associations at all, and that they are roughly spherical in form, has led to the following deductions: (1) associations are young and contain young stars, (2) associations are formed frequently, perhaps one every 100,000 years, (3) associations are expanding, the members separating from each other at an average rate of about 5 km. per second."

NUCLEAR REACTIONS IN STARS AND NUCLEOGENESIS, by A. G. W. Cameron, *Publications* of the Astronomical Society of the Pacific, June, 1957. "It is tempting to believe that our galaxy may have been originally composed entirely of hydrogen. About 7 billion years ago the Population II stars started condensing; the more massive of these evolved very quickly and ejected heavier elements into the interstellar gases. These heavy elements have been further processed by the stars which have formed since then."

Left: NGC 6744, in Pavo, is probably the largest barred spiral in the whole sky. It has a small, bright nucleus measuring 1.2 by 0.8 minutes of arc, an inner ring structure 3.1 by 2.0 minutes, and extensive filamentary and knotty arms with emission objects. An outlying cloud is 10.5 minutes north preceding at the end of a very faint anomalous arm. Reynolds size is 21.5 by 15.5 minutes, magnitude 9.1, enlargement 6.9x, scale 9.8.

Right: NGC 55, in Sculptor, is the largest Magellanic-type object after the Magellanic Clouds themselves; it is seen edgewise with the bar along the line of sight. It has many absorption markings, emission nebulosities, and supergiant stars of 18th magnitude and fainter. Reynolds size is 30 by 6 minutes, but on microphotometer tracings its major axis extends to about 50 minutes. It is a member of the large group of galaxies near the south galactic pole, and has a velocity of recession of 177 kilometers per second. Its magnitude is 7.8, enlargement 6.9x, scale 9.8.

CAPTIONS NOTE: The photographs in this article were all taken by the author with the 30-inch Reynolds reflector of Mt. Stromlo Observatory, in Australia. The "Reynolds size" given in each caption is the over-all dimension on the 30-inch plates; the magnitude is estimated integrated photographic; the enlargement is that of the reproduction compared to the original negative; the scale is in seconds of arc per millimeter of the reproduction.

A Survey of Bright Southern Galaxies

GERARD DE VAUCOULEURS, *Lowell Observatory*

OUR KNOWLEDGE of southern galaxies greatly lags behind that of galaxies visible to observers in mid-northern latitudes. Even in such well-known surveys as the Shapley-Ames investigation of objects brighter than the 13th magnitude (Harvard *Annals 88*, No. 2, 1932), the catalogued data for the brightest and largest southern galaxies are often unreliable or nonexistent. This is because of the absence of systematic photographic surveys such as were conducted at Lick, Mount Wilson, Harvard, Heidelberg, and other observatories for the northern and equatorial galaxies.

The history and current status of extragalactic studies in the Southern Hemisphere have been described by the writer in the *Occasional Notes* of the Royal Astronomical Society, III, No. 18, 1956, and more briefly in *Leaflet* No. 337 (June, 1957) of the Astronomical Society of the Pacific.

During an extended stay at the Australian Commonwealth Observatory, on Mt. Stromlo near Canberra (see *Sky and Telescope*, June, 1956, page 340), the writer photographed the bright galaxies listed in the Shapley-Ames catalogue south of declination −35°. From 1952 to 1955, the 30-inch Reynolds reflector was used, and in 1956 the new 74-inch telescope. The program was made possible by a research fellowship of the Australian National University.

About 250 one-hour exposures were obtained on Eastman 103a-O emulsion with the 30-inch reflector diaphragmed to 20 inches; this gave a focal ratio of f/6 and a plate scale of 67 seconds of arc per millimeter. On about 50 exposures with the 74-inch reflector, at f/5, the plate scale was 22.7 seconds of arc per millimeter.

The Reynolds plates were used to

determine new or revised types and dimensions for a total of 460 galaxies, generally larger than one minute of arc and of the 14th magnitude or brighter. These included 210 galaxies in the Shapley-Ames catalogue (out of 230 listed), 120 other galaxies from the *New General Catalogue* and the *Index Catalogues*, and 130 hitherto uncatalogued objects. Details of the data and their discussion have recently been published in the *Memoirs* of the Australian Commonwealth Observatory, III, No. 13, 1956.

Observations with the 74-inch reflector were used to fill in a few gaps left in the 30-inch survey and to replace some of the early or poor plates; in addition, photographs of some interesting objects were secured on the larger scale. For future microphotometric analysis, nearly all the plates secured with either reflector were standardized by means of a tube sensitometer. This material has not been completely reduced yet, and the published Mt. Stromlo survey is based exclusively on 30-inch plates.

Of special interest were the double and

NGC 300, in Sculptor, is one of the biggest ordinary spirals after M31 and M33, being very similar to the latter. It has a very small, globular-like nucleus, surrounded by extensive well-resolved arms of low surface brightness, including many emission nebulosities and supergiant stars of 17th magnitude and fainter. Reynolds size is 23 by 17 minutes, magnitude 8.5, enlargement 8.3x, scale 8.1. Like NGC 55, this galaxy is a member of the group near the south galactic pole. Its velocity of recession is 200 kilometers per second.

NGC 4945, in Centaurus, is one of the largest barred spirals in the sky. At the low galactic latitude of 12°, it is located so near the absorption belt of the Milky Way that interstellar matter dims its light appreciably. It has numerous dark markings and knotty arms, but it is not resolved into stars on the 30-inch plates. Reynolds size is 20 by 4 minutes; magnitude 7.8, enlargement 8.3x, scale 8.1. This galaxy forms a pair with the elliptical NGC 4976, 32 minutes distant, and it may also form a loose group with M83 and NGC 5253.

Left: NGC 1291, a barred spiral in Eridanus, is the largest and brightest member of the Fornax cluster and probably the biggest object with an outer ring structure in the whole sky. Its very bright core measures 1.1 by 1.0 minutes of arc, having a faint bar and still brighter nucleus within it. There is a regular bar 3.3 by 1.0 minutes in a bright lens 3.6 by 3.0 minutes (overexposed on the reproduction), surrounded by the outer ring of 8.2 by 7.3 minutes, at the rim of which emerge two very faint spiral arms. Reynolds size is 12 by 11 minutes, but on microphotometer tracings the major diameter is in excess of 20 minutes, corresponding to over 30 kiloparsecs at the distance of the Fornax cluster. Magnitude 9.4, enlargement 8.0x, scale 8.4.

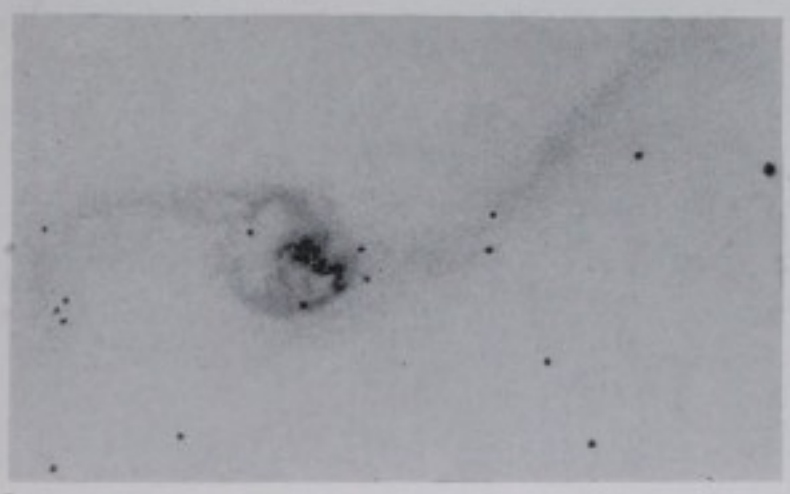
Right: NGC 1365, a barred spiral in Fornax, is one of the most conspicuous members of the Fornax cluster. It has a very bright, complex nucleus crossed by a twisted dark lane and long, regular arms with many knots and emission objects, but it is not resolved into individual stars on the 30-inch plates. Reynolds size is 11.4 by 6.6 minutes, magnitude 9.8, enlargement 7.4x, scale 9.2.

triple systems of galaxies found during the survey, some of them showing clear signs of tidal distortion in the components. For 30 pairs having no perceptible sign of interaction, the mean projected separation of the components is 18,000 parsecs (range eight to 45 kiloparsecs); for eight pairs showing distortion effects it is 6,500 parsecs (range three to eight kiloparsecs). The mean critical separation within which tidal distortion becomes notable is of the order of 10 kiloparsecs.

Two new pairs of colliding galaxies are NGC 1487 and 3256. In both cases multiple, distorted nuclei are surrounded by faint, curved filaments extending out to several minutes of arc from the center, an unmistakable indication of strong tidal interaction. Spectra of NGC 3256 taken recently with the Zeiss nebular spectrograph attached to the 74-inch reflector show strong hydrogen and ionized oxygen (λ3728) emission lines. The spectrum of NGC 1487 is still unknown.

Nevertheless, neither of these colliding systems appears to be a radio source, according to observations made by B. Y. Mills with the 1,500-foot cross-type radio telescope of the Radiophysics Laboratory near Sydney (see *Sky and Telescope*, November, 1955, page 24). However, the dense group of galaxies surrounding NGC 4696, pictured on the facing page, appears to be associated with a radio source, but no abnormal object could be detected in this field with the 30-inch reflector.

All in all, the search for optical identifications of strong radio sources or the radio detection of abnormal optical objects in the southern sky has proved most disappointing. The only positive identification, since that of the well-known Centaurus A with NGC 5128, is of Fornax A with NGC 1316, first suggested by the Russian astronomer I. S. Shklovsky, then independently by me in 1953, and firmly established by Mills in 1954.



NGC 3256, a colliding system of galaxies, sketched by the author from 30-inch reflector photographs. The fainter outer "tidal" filaments have been brought out by repeated copying for this highly enlarged negative reproduction, on which the scale is one inch to three minutes of arc.

The writer doubts, however, that these two systems, NGC 1316 and NGC 5128, can be regarded as instances of collisions between galaxies of the same type as those responsible for Cygnus A and Perseus A. While the latter have strong characteristic emission lines in their spectra, NGC 1316 and 5128 show normal *G*-type absorption spectra with little or no emission, and the radio/optical emission ratio is also much lower. The source and mechanism of the radio emission may therefore be different. It is noteworthy that extended radio sources surrounding a more intense "point" source are further common characteristics of Centaurus A and Fornax A; in both cases the radio intensity distribution is much broader than the optical brightness distribution, as reported at the Jodrell Bank symposium in 1955, by K. V. Sheridan and the writer.

A few erroneous entries in the Shapley-Ames catalogue were noted during the survey, the two most important ones being NGC 643 and 6026. The first

NGC 4696, in Centaurus, is surrounded by one of the densest fields of bright galaxies in the southern sky. This cluster includes NGC 4674, 4677, 4683, 4696, 4706, 4709, Helwan 281, 282, 283, together with half a dozen other nebulae larger than one minute of arc, and many smaller objects. In this region a radio source has been detected by radio astronomers at Sydney, Australia. The star field is rich because the galactic latitude is only 22°. The reproduction covers 66 by 56 minutes of arc, centered near NGC 4696, at $12^h\ 46^m.1$, declination $-41°\ 02'$ (1950 co-ordinates). The photograph was made with the 30-inch reflector on February 12, 1953, a 60-minute exposure on Eastman 103a-O emulsion; the telescope's aperture was reduced to 20 inches. Enlargement 3.7x, scale 18.2. The dark arrows indicate galaxies.

proved to be an outlying open cluster of the Small Magellanic Cloud, and the second was identified as a new planetary nebula only 20 degrees away from the galactic center. These identifications are discussed in the *Publications* of the Astronomical Society of the Pacific (*69*, 252, 1957; *67*, 418, 1955).

The Mt. Stromlo survey fills the last

Left: NGC 1313, in Reticulum, is probably the largest barred spiral of very late type in the whole sky, and it marks the transition stage toward the Magellanic-type objects. It has a vanishingly small nucleus in a bright bar measuring 1.8 by 0.4 minutes of arc, from which emerge two irregular and knotty arms full of emission nebulosities and supergiant stars of 19th magnitude and fainter. Note the characteristic asymmetry and similarity with small-scale photographs of the Large Magellanic Cloud, for example, in the "Astronomical Journal," Vol. 60, page 128, 1955. Reynolds size is 8.8 by 6.6 minutes, but on microphotometer tracings this galaxy can be measured out to 12.6 by 8.5 minutes, and still fainter extensions can be detected by repeated copying of long-exposure plates. Magnitude 9.5, enlargement 7.9x, scale 8.6.

Right: NGC 1566, in Dorado, is a typical transition type between ordinary and barred spirals of the S-shaped variety. It has a very small, very bright nucleus showing broad emission lines in its spectrum, which are an indication of high turbulent velocities (unpublished Mt. Stromlo spectra). In the overexposed central region a short bar is hidden, and from it emerge two bright regular arms with weak extensions whose Reynolds size is 8 by 8 minutes. Magnitude 9.5, enlargement 7.4x, scale 9.2.

Left: NGC 1672, in Dorado, is a bright member of a cloud of galaxies about 15 degrees north preceding the Large Magellanic Cloud. It has a small, very bright nucleus in the center of a regular bar about 2.4 minutes long, from which emerge two or three faint arms, one being brighter than the others. Reynolds size is 5.5 by 5.5 minutes, magnitude 10.7, enlargement 7.4x, scale 9.2.

Right: IC 5332, one of the biggest in a large group of spirals in Grus, is a little-known, ordinary spiral of very late type. It shows no definite nucleus on the 30-inch reflector plates, perhaps for lack of sufficient resolving power. Its many ill-defined, filamentary arms are reminiscent of M101. Reynolds size is 8.5 by 7.5 minutes, but longer exposures and better resolution would no doubt increase these values greatly. Magnitude 11.0, enlargement 7.3x, scale 9.3.

Left: NGC 1448, in Horologium, is a little-known, late-type spiral about 10 degrees south of the Fornax cluster. It is strongly tilted to the line of sight. Reynolds size 7.5 by 1.8 minutes, magnitude 11.0, enlargement 7.4x, scale 9.2.

Right: NGC 7793, in Sculptor, is the prototype of the very late stage Sd as given by Shapley in 1940. It has a very small, globular-like nucleus and many ill-defined knotty arms, with emission objects and supergiant stars of 18th magnitude and fainter. Reynolds size 10 by 7 minutes, magnitude 9.3, enlargement 7.3x, scale 9.3. A member of the group near the south galactic pole, this galaxy has a velocity of recession of about 250 kilometers per second. A detailed description was given in Harvard Observatory "Bulletin" No. 907, 1938.

major gap in our exploration of the nearer external galaxies in the southern hemisphere. Earlier and current work at Mount Wilson and Palomar, Lick, Harvard, Lowell, Helwan, and Heidelberg observatories provide the elements for a nearly complete coverage of northern and equatorial objects down to about 30° south declination. There remains a weak zone between −30° and −35°, where only incomplete and obsolescent data are available, which could not be included in the 30-inch survey because of instrumental limitations. This zone could easily be covered now with either the 74-inch reflector at Canberra or the one at Pretoria, South Africa. Eventually all the brighter galaxies south of −30° should be rephotographed in two colors with these instruments, in order to provide better material for an improved morphological description and classification of the southern galaxies.

A systematic program of photography of the brighter galaxies south of −26° has been in progress for nearly 10 years at the Radcliffe Observatory, Pretoria, but only recently have details become available (see page 519).

In the meantime, the results of the writer's Mt. Stromlo survey will be incorporated in a general revision of all types, magnitudes, and dimensions of the 1,250 brighter galaxies listed in the Shapley-Ames catalogue. This revision, in progress since 1949 (*Astronomical Journal, 61,* 430, 1956; *Annals* of the Houga Observatory, II, No. 1, 1957), is now approaching completion.

The Twelve Brightest Galaxies

NGC	R.A. (1950) h	m	Dec. °	′	*l* °	*b* °	Const.	Type	m_t	(m_h)	Size °		′	Dist. Mpc.
LMC	05	24	−69.8		247	−33	Dor	SBm	0.2	(0.5)	21	×	19	0.045
SMC	00	51	−73.1		269	−45	Tuc	SBmp	2.5	(1.5 :)	7	×	4	0.045
224	00	40	+41.0		89	−21	And	Sb	4.00	(5±)	4	×	1	0.45
598	01	31	+30.4		103	−31	Tri	Sc	6.05	(7.8)	1	×	0.5	0.45
5128	13	22.4	−42°	45′	278	+18	Cen	Sop	6.5 :	(7.2 :)	0.5	×	0.3	0.75 ?
			°	′							′		′	
Scul	00	57.5	−33	58	241	−83	Scl	dE	7.1 :	(9.0 :)	45	×	40	0.07
Forn	02	37.5	−34	44	203	−64	For	dE	7.5 :	(9.5 :)	50	×	35	0.15 :
253	00	45.1	−25	34	100	−88	Scl	Sc	7.5 :	(7.0 :)	21	×	5.3	1.5 ?
5236	13	34.3	−29	37	284	+32	Cen	SBc	7.5 :	(8.0 :)	10	×	9	2 :
3031	09	51.5	+69	18	108	+42	UMa	Sb	7.75	(8.1)	22	×	10	2.5
55	00	12.5	−39	30	295	−77	Scl	SBm	7.8 :	(7.8 :)	30	×	4.0	1.5 ?
4945	13	02.4	−49	01	273	+12	Cen	SBc :	7.8 :	(9.2 :)	15	×	2.5	2 :

Twenty Bright Southern Galaxies

NGC	R.A. (1950) h	m	Dec. °	′	*l* °	*b* °	Const.	Type	m_t	(m_h)	Size ′		′	Dist. Mpc.
247	00	44.6	−21	01	94	−83	Cet	Sc	9.4	(10.7)	18	×	5.5	1.5 ?
300	00	52.6	−37	58	258	−80	Scl	Scd	8.5	(11.3 :)	20	×	15	1.5 ?
1291	03	15.5	−41	17	213	−56	Eri	SBo	9.4	(10.2)	8	×	7.5	5 :
1313	03	17.6	−66	40	250	−44	Ret	SBcd	9.5	(10.8)	9	×	8	5 ?
1316	03	20.7	−37	25	207	−55	For	Sop	9.5	(10.1)	5	×	3	5 :
1365	03	31.8	−36	18	203	−53	For	SBc	9.8	(11.2)	7.5	×	5.5	5 :
1553	04	15.2	−55	54	232	−43	Ret	So	9.6	(10.2)	4.0	×	3.0	5 :
1566	04	18.9	−55	04	230	−43	Dor	Sc	9.5	(10.5)	6	×	5	5 :
2427	07	35.1	−47	30	227	−12	Pup	Scd	9.9 :	(12.4 :)	5.5	×	2.5	?
2997	09	43.5	−30	58	231	+18	Ant	Sc	9.4	(11.0)	7	×	5.5	7 :
4594	12	37.3	−11	21	268	+51	Crv	Sab	8.9	(8.1 :)	6.5	×	2.0	4 ?
4976	13	05.9	−49	14	274	+12	Cen	E5	9.7	(11.6)	3	×	1.5	2 ?
5253	13	37.1	−31	24	284	+30	Cen	I :	9.8 :	(10.8)	3.5	×	1.5	2 :
5643	14	29.4	−43	59	289	+14	Lup	Sc	9.7	(11.4)	3.0	×	2.5	?
6215	16	46.8	−56	55	297	−10	Ara	Sc	9.7 :	(11.2)	2.0	×	1.5	?
6221	16	48.5	−59	08	298	−11	Ara	SBc	9.6 :	(11.4)	3.0	×	2.0	?
6300	17	12.3	−62	46	295	−15	Ara	SBb	9.9 :	(11.4 :)	2.5	×	2.0	?
6744	19	05.0	−63	56	300	−27	Pav	SBbc	9.1 :	(10.6)	15	×	10	2 ?
6822	19	42.1	−14	53	354	−20	Sgr	Im	8.9	(11.0 :)	20	×	10	0.3 :
7793	23	55.3	−32	51	330	−78	Scl	Sc	9.3	(9.7)	6.5	×	4.5	1.5 ?

SYMBOLS: *l*, galactic longitude; *b*, galactic latitude; m_t, total photographic magnitude; m_h, Harvard magnitude, given only for comparison. Distances, in megaparsecs, are mostly rough estimates from assumed memberships in several groups.

A Probable Meteorite Crater of Great Age

C. S. Beals, *Dominion Observatory, Ottawa*

ALTHOUGH meteorite craters have been found in every major land mass except Antarctica, it must be admitted that their numbers (between 30 and 40) are statistically not very impressive when compared to the number of such craters that appear to exist on the moon. Thus, the addition of even a single terrestrial crater such as the one described here increases our data appreciably.

Recent investigations have broadened our knowledge in directions other than numbers alone. For example, the discovery by M. J. S. Innes of a large crater at Deep Bay, Saskatchewan, has extended the size of terrestrial craters to approximately seven miles in diameter.

In the matter of age, the Brent crater and the Holleford crater are filled with Paleozoic sediments, giving indication that some meteorite-crater ages must be reckoned in hundreds of millions rather than tens of thousands of years. Modern theories of the origin of the solar system make these old craters especially significant since they *may* represent the final stages in a process of accretion that formed the earth.

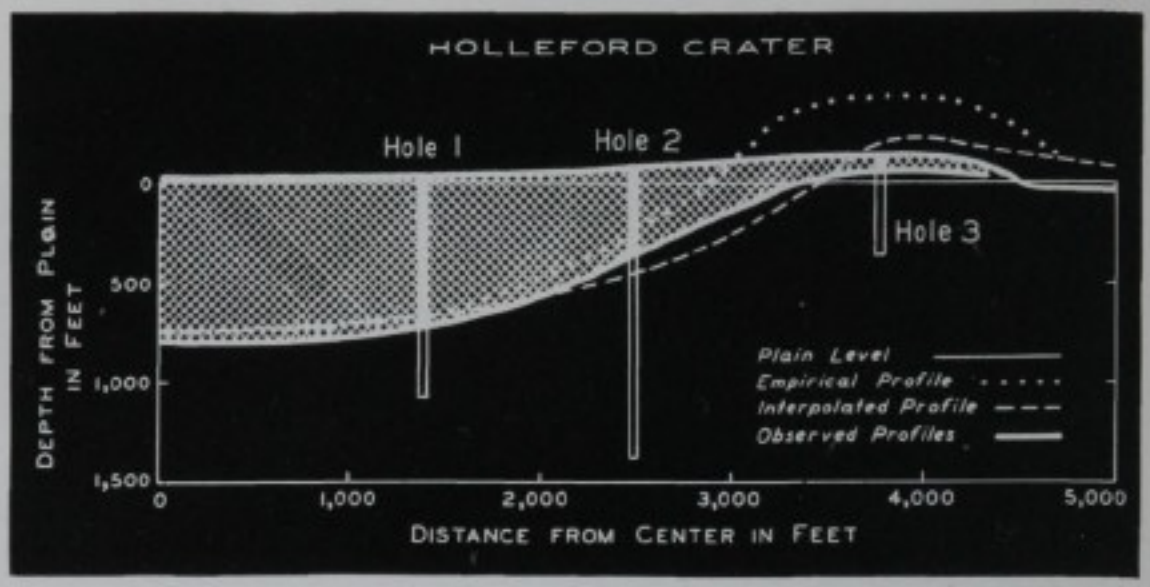


Fig. 1. In this cross-sectional diagram of Holleford crater, the hatched region is the filling of Paleozoic sediments. Its observed profile (heavy line) agrees well with J. A. Rottenberg's predicted profile (dotted line), when allowance is made for erosion of the rim of this very old crater.

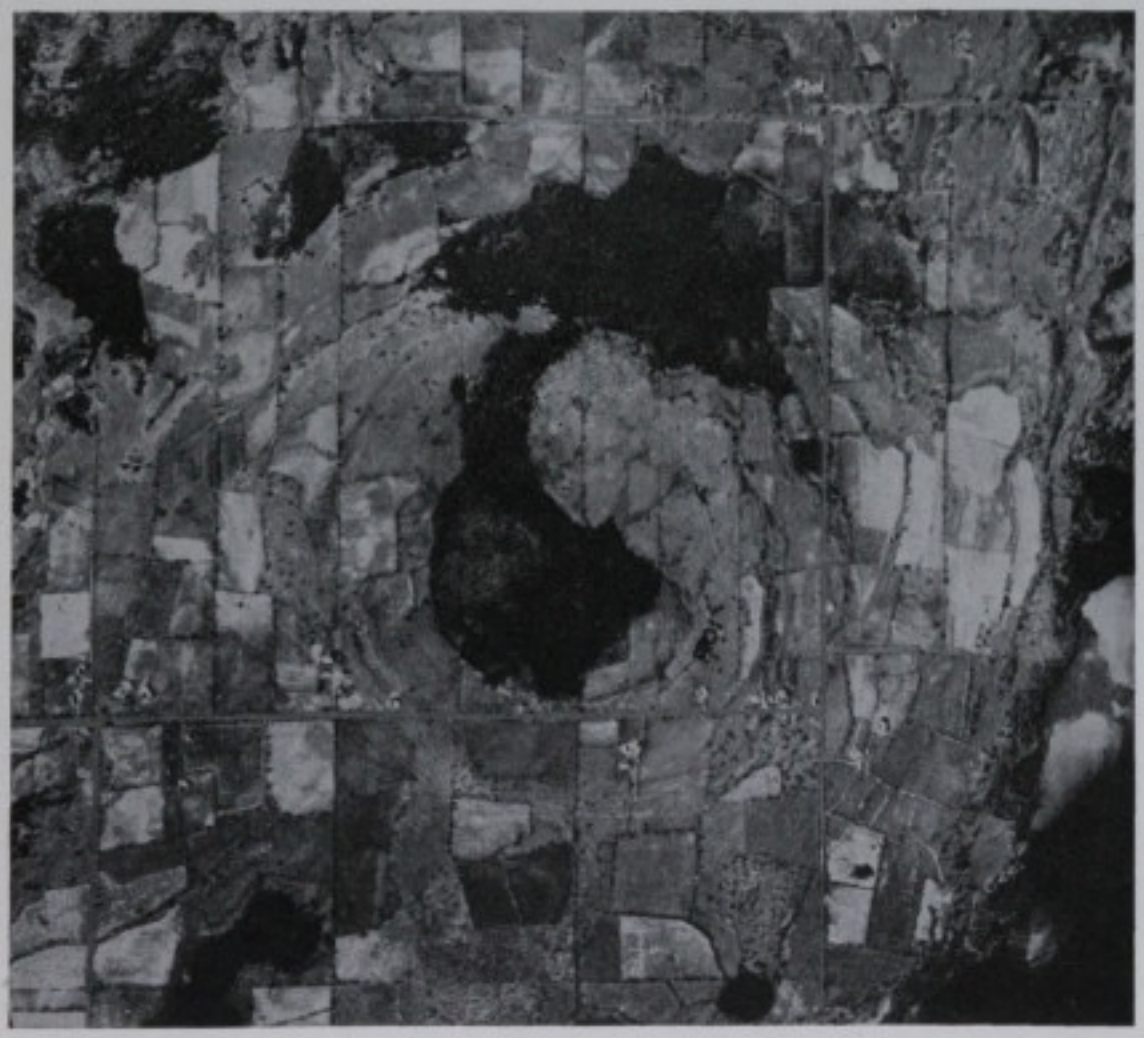


Fig. 2. Is this the scar of a great meteorite that fell several hundred million years ago? The above Royal Canadian Air Force photograph of Holleford crater in Ontario was taken from an aircraft flying at 8,420 feet. As reproduced here, one inch corresponds to $\frac{3}{8}$ mile. Most of the crater interior is farm land, and the dark central area is a wooded bog.

The Holleford crater is located in Ontario, at latitude 44° 47′ north, longitude 76° 38′ west. It was described in *Sky and Telescope* for May, 1956, page 296, where the aerial view of Fig. 2 was published. Now we can discuss the results of drilling operations recently carried out at Holleford to secure more definite evidence about the origin of this formation, whose age has been estimated as at least 500 million years.

This moderately conspicuous depression is 100 feet deep and 1.46 miles in diameter. While the Paleozoic sediments in the area immediately surrounding the crater are of the order of 50 to 100 feet thick, geophysical observations have indicated that there is a considerable depression in the Pre-Cambrian basement rocks under the observed circular field—this depression may have been caused by meteoritic impact in Pre-Cambrian or early Paleozoic time.

From the drillings, we hoped to find the depth to the floor of the prehistoric crater, as well as the depth of the original rim. Three holes were bored at distances of 1,400 feet, 2,500 feet, and 3,750 feet from the center, to depths of 1,128, 1,486, and 443 feet, respectively.

On the basis of known characteristics

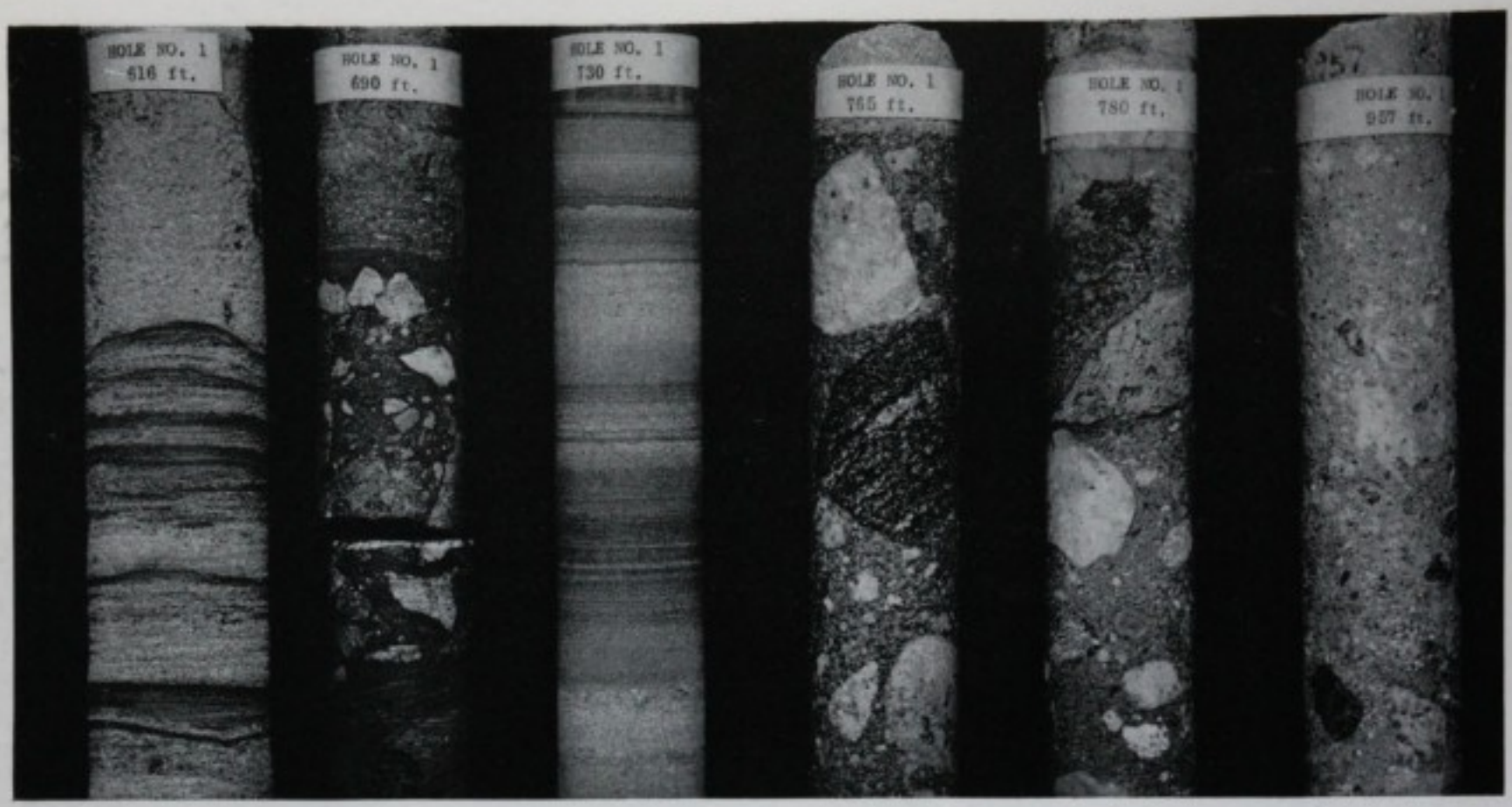


Fig. 3. Compare these rock cores from hole No. 1, drilled in the interior of Holleford crater. The sediment layers to the left contain interbedded breccia at a depth of some 690 feet. At the right are three samples of fragmented material from beneath the original crater floor, between 765 and 957 feet below the present surface.

of meteorite-impact craters, we could estimate the depth to the original floor at any distance from the center. For the guidance of the drillers, this was roughly estimated as 800 and 400 feet for the first and second holes, respectively. Actually, in the first hole the floor was encountered at 750 feet, and in the second at 415 feet.

The third hole was bored through the sediments covering the vestiges of the original crater rim, which were encountered at a depth of 64 feet. We may conclude that most of the original rim was eroded before the deposition of sediments began.

How well the predicted and observed profiles agree is shown in Fig. 1. The dotted line is drawn from an empirical formula kindly supplied by Dr. J. A. Rottenberg of the Dominion Observatory. The dashed line is interpolated between the observed profiles of the Barringer crater in Arizona and the New Quebec (Chubb) crater in Ungava. Considering the extent of divergence between the two predicted profiles, it can scarcely be said that there is any real disagreement between observation and prediction.

A crater produced by meteorite impact and explosion should have a floor consisting of broken and fragmented materials such as rock breccia, rock flour, and conglomerate. As illustrated in Figs. 3, 4, and 5, the material under the floor level consists of broken, granulated, and powdered rock weakly recemented. The first hole penetrated 375 feet of this material without getting through to the undisturbed Pre-Cambrian. The second hole went through the fragmented material, which was found to have a thickness of about 500 feet. While the first few hundred feet consist of a mixture of various sizes of rock fragments, approximately 400 feet below the floor the rock is uniform in character and appears to be broken and fractured in places—an interpretation tentatively advanced pending a more thorough geological examination of the cores.

From the whole of the evidence, it appears that Holleford crater is a circular depression with original contours closely similar to those of known meteorite craters. In addition, the existence of several hundred feet of fragmented material under the floor is in accord with formation by explosion or meteoritic impact. While it may be assumed that any type of explosion of sufficient violence could have formed the crater, meteorite impact would appear the most probable. An explosion from below does not seem very likely in the type of Pre-Cambrian

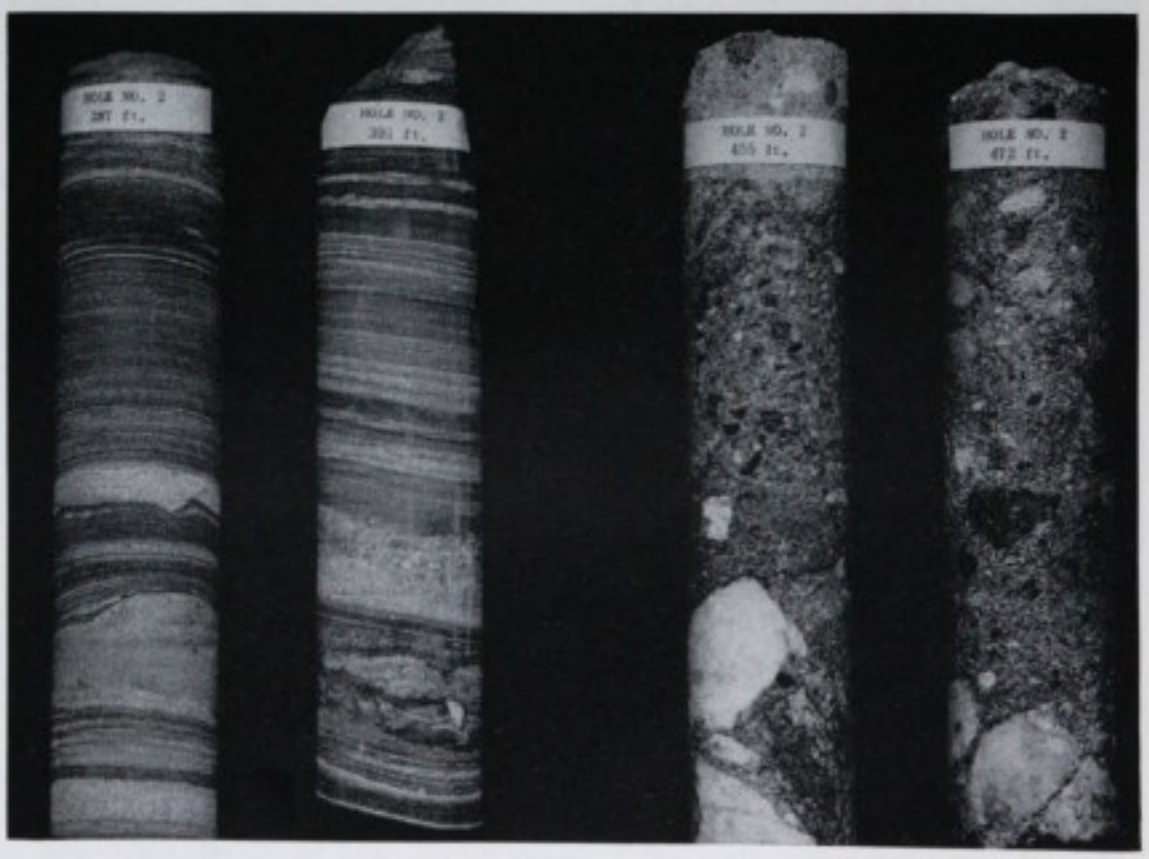


Fig. 4. Cores from hole No. 2. The two samples at the left show sedimentary material from about 390 feet down, still above the original crater floor. But the other samples, taken as little as 64 feet deeper, show granulated rocks from under the floor.

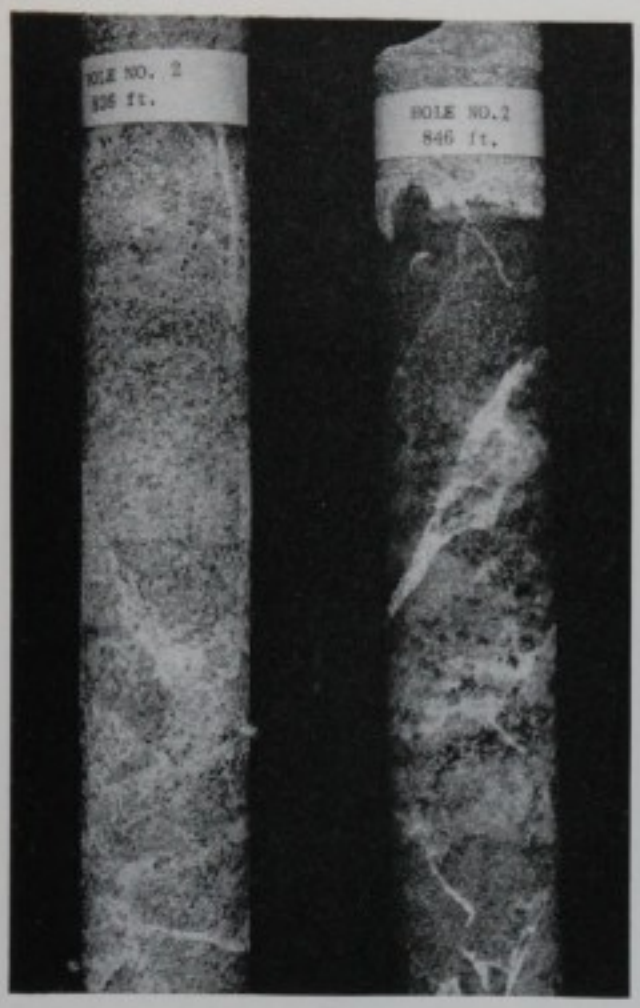


Fig. 5 (left). Two deeper cores from hole No. 2 show rock shattered in place, presumably by shock wave from the impact.

Fig. 6 (right). From still deeper in hole No. 2, four cores show undisturbed Pre-Cambrian rock. Their fractures are of a kind common to such rocks, and are probably unrelated to the crater-forming process.

rock in which the crater was formed, and so far no type of disturbance other than meteorite impact has been suggested as likely to come from above the ground.

The cores are being searched for meteoritic material, but none so far has been found. Each drill core is about 1¼ inches in diameter and represents only 5×10^{-9} of the crater surface at any given level, so the probability of finding meteoritic fragments even if they existed would be slight, to say the least.

Actually, it would seem unlikely that metallic fragments could survive as such over very long periods of time, and their oxides or other chemical combinations might be difficult to identify. It is also possible that the meteorite that might have formed this crater, which is so far removed in time from already well-authenticated objects like the Barringer crater, might have consisted of entirely different material much more difficult to distinguish from terrestrial rock than are present-day meteoritic falls.

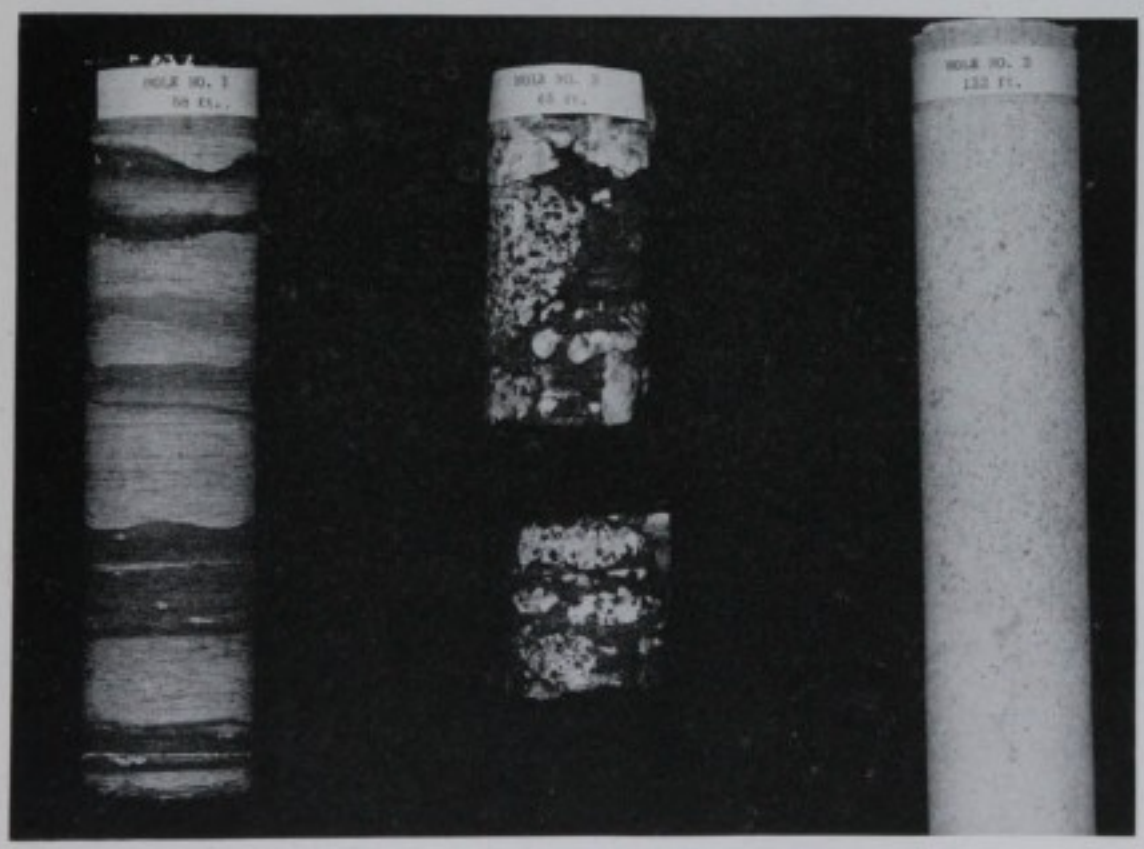


Fig. 7. These three core samples are from hole No. 3, drilled to locate the crater rim. At the left is sedimentary rock covering the rim, and in the middle is part of a foot-thick layer of conglomerate or breccia at 65 feet. The specimen at the right is undisturbed Pre-Cambrian rock secured at a depth of 132 feet, under the original crater rim. All core-sample pictures with this article are from the Dominion Observatory.

NEW NAKED-EYE COMET

On the morning of August 2nd, Antonin Mrkos in Czechoslovakia discovered a new 3rd-magnitude comet in Cancer. Twenty hours later, S. M. Laustsen at Copenhagen Observatory found it to be 2nd magnitude. According to Copenhagen observers, on August 3rd at 21:04 Universal time, the comet was at right ascension $8^h\ 29^m.9$, declination $+34°\ 40'$, moving 11 minutes of time eastward and one degree northward per day. Thus the new object, Comet 1957d, was becoming more favorably placed for Northern Hemisphere observers, being then visible both in the northwest after sunset and in the northeast before dawn.

This conspicuous comet was independently found by several United States airline pilots. Among them, Peter Cherbak saw it about five degrees east of Castor on July 31st and August 1st.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 97th meeting of the American Astronomical Society at Cambridge, Massachusetts, in May. Complete abstracts will appear in the Astronomical Journal.

Rotation of the Galaxy

Since J. H. Oort first analyzed the motions of supergiant stars 30 years ago, it has been known that stars in the Milky Way galaxy inside the sun's orbit about the nucleus have shorter periods than the sun, and therefore overtake and pass us. Those outside the sun fall behind.

If most of the mass of the Milky Way were concentrated in the nuclear region, the stars at various distances would follow orbits that obeyed Kepler's laws of planetary motion, and the outward decrease of velocity could be exactly predicted. But if the mass in the galaxy were distributed with a constant density from center to edge, then simple dynamical considerations show that the whole system would rotate as a solid wheel, and the inner stars would neither gain nor lose on the outer ones. The true situation lies somewhere between these hypothetical extremes.

The differential motion is important to the radio astronomers who study interstellar hydrogen by its 21-cm. emission. Not only does the Doppler effect separate the radiation of other spiral arms from local hydrogen radiation, but the *rate of velocity change with distance* is important in locating the hydrogen in space. This rate change, Oort's constant A, can be determined from the measured radial velocities of stars if their distances are known. Many stars must be averaged to smooth out the random motions. Earlier attempts were plagued by the difficulty of allowing for absorption by interstellar dust in the distance calculations.

J. D. Bahng, A. D. Code, and A. E. Whitford, of Washburn Observatory, University of Wisconsin, have used improved data on the distances of *B*-type stars and Cepheid variables in a new study of the value of A. Only stars with their absorptions determined by measured color excesses were included. The value of A turned out to be 11.5 ± 1.5 kilometers per second for each 1,000 parsecs. This is on the side of the "low" values recently derived by H. F. Weaver, and disagrees seriously with the value of 20 kilometers per second per kiloparsec used by Oort in his model of the galaxy and by the Leiden radio astronomers. The disagreement is believed to stem from the scale of distances used; for the *B* stars this rested on W. W. Morgan's spectroscopic luminosity criteria.

Most of the stars were contained in a zone reaching out two kiloparsecs on either side of the sun's orbital path around the nucleus, but a few *B* stars were located as much as five kiloparsecs inward from the sun. All of the *B* stars were used to plot a curve of velocity as a function of distance from the center, assuming particular values of the sun's distance and orbital velocity.

The most striking feature of the Wisconsin results is the rapid decrease in galactocentric velocity inward from the sun, suggesting a close approach to solid-wheel rotation in the inner parts. This implies a smaller concentration of mass in the bright nucleus of the galaxy than had previously been assumed. The curve is not unlike a similar plot by N. U. Mayall for our neighbor galaxy in Andromeda, M31.

The velocity curve determined from the motion of *B* stars departs markedly from a similar curve derived by Kwee, Muller and Westerhout from 21-cm. hydrogen observations, also shown on the graph. This disagreement is puzzling. If the stars and the gas do not rotate together, then the usual assumption of circular orbits is not justified, or some other force besides gravitation is acting on one of them.

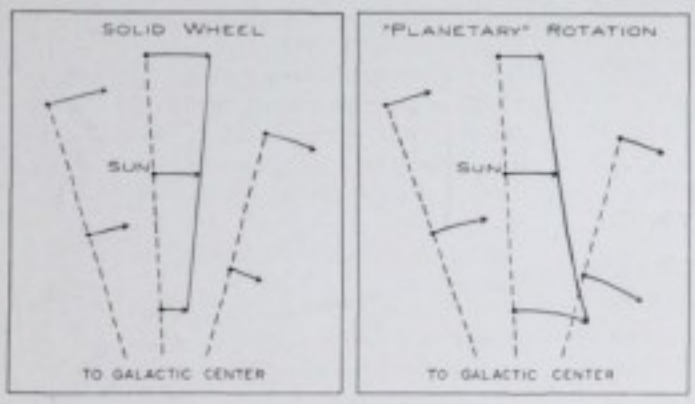
2,500 Meteor Orbits

When we photograph the same meteor from two stations 20 or 30 miles apart, we can calculate the orbit it had around the sun before falling through the earth's atmosphere. The calculation is laborious, if utmost accuracy is sought, yet many such orbits must be known to provide a statistical picture of the motions of small bodies in the solar system.

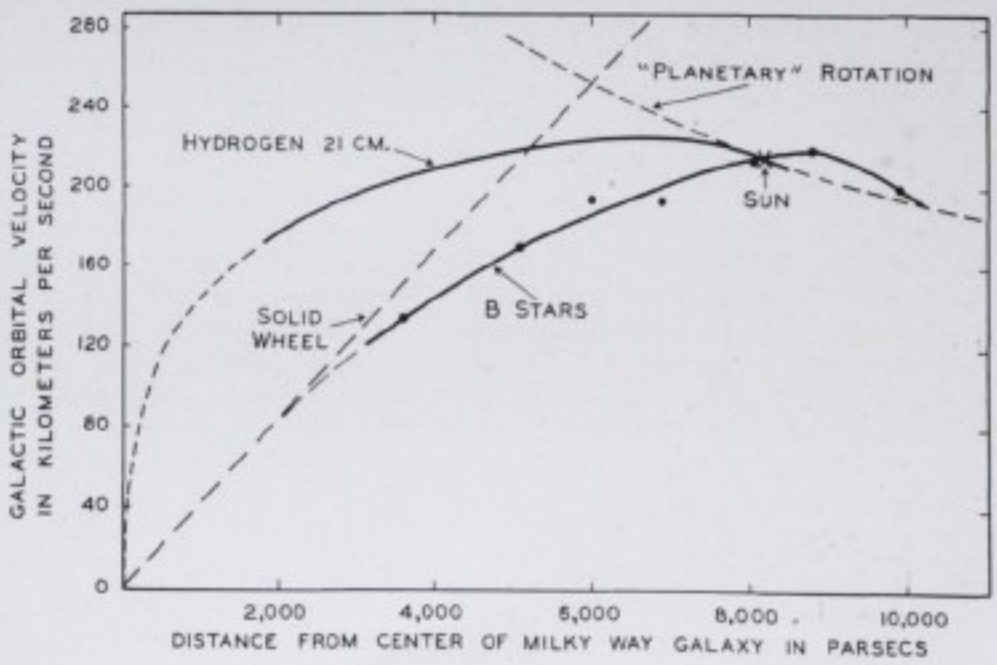
At Harvard Observatory, Richard E. McCrosky has developed mass-production methods for measuring meteor photographs and deducing their orbits, with the aid of graphical processes and a large transparent plastic hemisphere that represents the sky. He has obtained the approximate velocities and orbital elements of 2,500 meteors recorded by the super-Schmidt meteor cameras in New Mexico between February, 1952, and July, 1954.

The great majority of the orbits are nearly circular. While some 10 per cent appeared to be hyperbolic, as if these meteors were not following closed orbits around the sun, Dr. McCrosky believes them to be simply cases in which the deduced velocities came out a few per cent larger than they actually were. On the average, the errors in velocities were four per cent. Meteor heights above the ground were determined with about three-per-cent accuracy, and the radiant point of each meteor could be found within a few degrees.

Most significant is the result that meteoric particles traveling around the sun in the same direction as the earth are several hundred times as numerous as those moving in the opposite direction. This great predominance of direct over retrograde meteors was first established in 1950 by G. S. Hawkins from radar observations



Above: A comparison of stellar motions in solid-wheel and planetary-type galactic rotation.



Right: A solar velocity of 216 kilometers per second is assumed here, with the galactic center 8,200 parsecs away. The two inner points are based on three and seven B stars, respectively, the others on 34 or more. Washburn Observatory diagram.

at Jodrell Bank, England; his final results were published in 1956. Dr. McCrosky's analysis began by noting how the observed radiant points were distributed over the sky, and then correcting this distribution for the fact that the observations were made from a moving earth.

This computation by itself would have given about 50 to 1 for the relative numbers of direct and retrograde meteors. But the retrograde meteors can collide head-on with the earth, becoming bright and easily photographed, whereas direct-moving bodies enter the atmosphere more slowly after a stern chase, and so may be too faint to be recorded, even though they are larger. Applying an allowance for this gives the actual ratio of several hundred to one.

Practical Use for Radio Sources

Project Betty of the Army Map Service is a program for the determination of the precise geographical co-ordinates of certain Pacific islands, from which the radio signals sent out by the artificial satellite will be observed.

Werner D. Kahn, of the Army Map Service, described the Minitrack Mark II system that will be used to pick up the 108-megacycle signals. Each field installation will be a radio interferometer 800 feet long, which will be used as a transit instrument to record the time of meridian passage of the satellite.

At a prototype station, the accuracy of observation and the instrumental calibration were checked by repeated records of transits of two strong radio sources, Taurus A and Cassiopeia A. In this practical application of radio astronomy to geodesy, it was found that the mean error of an individual observation of right ascension was ±46 seconds of arc.

Identification of Coronal Lines

Astrophysicists continue their efforts to identify more of the bright spectral lines of the sun's corona. Recently, the coronal line at 4086 angstroms was shown in the laboratory to originate from calcium XIII (calcium atoms that have lost 12 of their electrons). Harold Zirin, High Altitude Observatory, has made use of this identification to test the belief that the yellow coronal line at 5694 angstroms is due to an even more highly ionized state of this atom, calcium XV.

He observed the spectrum of the corona in the vicinity of a strong solar limb flare on December 18, 1956, finding both the 4086 and 5694 lines present. Their intensity variations were similar during the progress of the flare; and the widths of the two lines both indicated the same temperature of about 10 million degrees centigrade, if calculated on the assumption that the line broadening was entirely a thermal effect. These correspondences make it seem quite probable that the 5694 line is actually due to calcium XV.

Also at the High Altitude Observatory, M. C. Bretz and D. E. Billings have found evidence that another line, of wave length 5446 angstroms, is due to calcium XV. In coronal spectrograms secured on November 12, 1956, near an active sunspot region, the 5446 and 5694 emission lines showed similar behavior.

Star Cluster Lifetimes

It is well known that a cluster of stars tends to eject some of its members, since close encounters between them occasionally accelerate a few to move faster than the velocity of escape. For instance, a cluster like the Pleiades may be expected to lose about one per cent of its stars in the next 20 to 30 million years.

As its stars gradually escape, a cluster contracts, and this contraction will increase the rate of ejection. Now, at the University of Illinois Observatory, Ivan King has calculated the effect of the contraction on the lifetime of the cluster, extending earlier work by V. Ambarzumian, L. Spitzer, S. Chandrasekhar, and others.

Dr. King finds that the contraction will materially hasten the decay of the cluster, and that the last stage of dissolution will be comparatively very rapid. In a billion years the Pleiades will have lost half its stars, but within the following 100 million years it will cease to exist as a cluster.

Internal Structure of Jupiter and Saturn

W. DeMarcus, Union Carbide Nuclear Co., has used the following approach to the problem of describing the interior of a giant planet, such as Jupiter, which is known to be composed mainly of hydrogen.

Consider a model of pure, cold hydrogen having the same total mass as the planet. Then, knowing the physical properties of hydrogen, the radius that the hypothetical model planet will have can be calculated. If this should check with the observed size of the planet, the computed properties of the model, such as its central temperature and pressure, may be expected to hold true for the actual planet. Earlier but not entirely conclusive calculations of this sort had been made by R. Wildt, W. Ramsay, and by Dr. DeMarcus.

In the new work, an improved equation of state for hydrogen was used, based in part upon recent measurements, by J. W. Stewart at the University of Virginia, of the compressibility of hydrogen under pressures as great as 20,000 atmospheres. The new calculations confirm that the extremely compressed cores of Jupiter and Saturn should consist of the metallic form of solid hydrogen, which can exist only under great pressure and low temperature.

The only element other than hydrogen that may be expected to form a major constituent of the giant planets is helium. The observed size of Jupiter can be reproduced by the calculated model if the planet is 78 per cent hydrogen by weight and 22 per cent helium. The corresponding hydrogen abundance for Saturn is 65 per cent.

Filamentary Structure in Diffuse Nebulae

At Mount Wilson and Palomar Observatories, Donald E. Osterbrock has studied several diffuse nebulae that have parallel bright threadlike structures. These nebulae are IC 434, containing the Horsehead dark nebula in Orion and for which the filamentary structure was first described by J. C. Duncan; NGC 1499, the California nebula in Perseus; and NGC 2327, in Canis Major.

In each case, bright and dark nebulosities occur near a hot star of spectral type *O*. There is a bright rim separating the luminous and nonluminous material, and the parallel filaments begin at the rim and extend more-or-less perpendicular to it. Dr. Osterbrock believes that the *O* star is ionizing one side of a relatively dense, nonionized, dark cloud. The ionized matter becomes luminous and expands into the near vacuum of space on its side of the dark cloud, extending in some cases beyond the *O* star.

He believes that the bright threads result from regions of high density in the original cloud that are drawn out by the motion of expansion without being mixed appreciably. It is not clear why such threads can preserve their identity. One suggestion by Dr. Osterbrock is that a magnetic field may be present, preventing motions perpendicular to its own direction; the filaments would thus be similar in origin to the polar rays in the sun's corona. Another possibility is that the turbulence mechanism that is common to most diffuse nebulae does not operate in these cases.

FACING PICTURE: A portion of a photograph in red light, taken with the 48-inch Schmidt telescope of the Palomar Observatory, with north at the top. It shows the system of filaments involved in the bright nebulosity IC 434, which extends vertically along the left part of the field, being interrupted by the dark absorption of the Horsehead nebula. The star Epsilon Orionis, in the middle of Orion's Belt, is at the upper right, its image very much overexposed. Mixed with the nebulosity in the upper part of IC 434 is the image of Zeta Orionis, also in the Belt, and to its left is the large diffuse nebula NGC 2024. Above these, surrounding a star, is the spherical emission feature, IC 432, while below them, seen against the dark nebula along the left edge of the picture, are the diffuse nebulae NGC 2023 and IC 435, the latter small. Nearly in the center of the field is Sigma Orionis, a hot blue star of spectral type B0. The irregular circles in the lower right are ghost images of the star Zeta Orionis, caused by internal reflections in the telescope. Mount Wilson and Palomar Observatories photograph.

Here and There with Amateurs

Most of these societies hold regular meetings once or twice monthly, at which interested persons are always welcome. Details of each society's program can be obtained from the official whose name and address are given here.

*Members receive *Sky and Telescope* as a privilege of membership.

†Member organization of the Astronomical League.

‡Member organization of the Western Amateur Astronomers

°Society has junior section.

☆Independent junior society.

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HARRISBURG
Astronomical Society of Harrisburg *†
E. L. Naylor, 320 Wilhelm Rd. CE 2-6479
MILLVALE
Shaler Township Junior Amateur Astronomers ☆
C. Raible, 200 Rebecca Sq. (9). TA 1-2171
PHILADELPHIA
Amateur Astronomers of Franklin Inst. †
E. F. Bailey, Franklin Inst. (34). LO 4-3600
Rittenhouse Astronomical Society *†
J. W. Streeter, Franklin Inst. (34). LO 4-3600
PITTSBURGH
Amateur Astronomers Ass'n. of Pittsburgh *†*
F. Garland, 127 Park Pl., McKnight Village (9).
SPRINGDALE
Allegheny Valley Amateur Astronomers **
W. E. Stocks, 215 Carson St. SP 1980-W
YORK
York Astronomical Society *
J. N. Lewis, 157 Scarboro Dr. 8-1080

RHODE ISLAND

NORTH SCITUATE
Skyscrapers, Inc.
H. W. Preston, Bishop Heights. SC 1-3256

SOUTH CAROLINA

HARTSVILLE
Hartsville Astronomical Society ☆
B. Hopkins, Box 423. 1540

SOUTH DAKOTA

RAPID CITY
Rapid City Astronomical Society *
Dr. R. F. Heckman, S. D. State School of Mines and Technology.

TENNESSEE

BRISTOL
Bristol Junior Astronomical Society ☆
H. Snow, 618 Center Dr.
CHATTANOOGA
Barnard Astronomical Society *†
A. H. Jones, 411 W. 21st St. VE 1-2244
KINGSPORT
Kingsport Astronomical Society *
J. Brown, 1409 Belmeade Dr. CI 5-7513
MEMPHIS
Memphis Astronomical Society *†
G. P. Turner, 3713 Wilshire Rd. FA 3-8490
NASHVILLE
Barnard Astronomical Society *
Dr. C. K. Seyfert, Vanderbilt Univ. AL 4-5611
PORTLAND
Portland Astronomical Society †
R. O. Riggs, Box 42. 3781

TEXAS

ABILENE
Abilene Astronomical Society *
R. B. Edmundson, 1849 N. 8th St. OR 4-5932
BROWNFIELD
Brownfield Astronomy Club *
C. Isbell, Rte. 1. 2074
DALLAS
Texas Astronomical Society †*
E. M. Brewer, 5218 Morningside Ave. (6). TA 6-3894
FT. WORTH
Ft. Worth Astronomical Society *†
J. M. McMillen, 604 Tierney Rd. JE 6-8525
Junior Astronomy Club of Children's Mus. †☆
Miss C. M. Noble, 1511 Cooper St. (4). ED 2-9892
HOUSTON
Houston Amateur Astronomy Club *
W. W. Myers, 7424 Tipps St. (23). WA 6-5947
KILGORE
East Texas Astronomical Society *
T. H. Anderson, Jr., 601 Highland Dr.
LAREDO
Laredo Astronomy Club *
S. Freidin, Box 1148. 3-8345
PORT ARTHUR
Port Arthur Astronomy Club *†
Mrs. W. C. Piggott, 5228 5th St. YU 3-2448
SAN ANGELO
San Angelo Amateur Astronomers Club *
A. Clark, 1112 Algerita Dr. 2-1622
SAN ANTONIO
San Antonio Astronomy Club *†
S. Friesenhahn, 242 Peck. LE 3-7878

UTAH

SALT LAKE CITY
Astronomical Society of Utah *
J. W. Geertsen, 4461 S. 9th East St. (17). AM 6-4602

VERMONT

SPRINGFIELD
Springfield Telescope Makers †
C. R. Ranney, 3 Hillcrest Rd. TU 5-2436

VIRGINIA

HARRISONBURG
Astral Society
R. C. Lehman, Eastern Mennonite College. 4-7370

HERE AND THERE WITH AMATEURS

(Continued from page 533)

NORFOLK
Norfolk Astronomical Society *†°
A. D. Hustead, Weather Bur., Municipal Airport (13). LO 3-4368
RICHMOND
Richmond Amateur Junior Astronomers ☆
Dr. E. C. Hoff, 117 Gaymont Rd. (26). 88-3368
Richmond Astronomical Society *†
B. S. Ragland, 601 E. Franklin St. (19). 2-3043
ROANOKE
Amateur Astronomers of Roanoke *†
W. B. Daniel, 2202 Richlieu Ave. S.W. 3-2637

WASHINGTON

SEATTLE
Seattle Amateur Astronomical Society *†°
N. C. Dalke, 8017 Strood Ave. (3). PL 7498
SPOKANE
Amateur Telescope Makers of Spokane *†
Miss D. Caputo, 2718 E. 18th. KE 5-1005
TACOMA
Tacoma Amateur Astronomers †
Mrs. R. H. Atkinson, 2816 N. Union Ave. (7). PR 1492
YAKIMA
Yakima Amateur Astronomers *†
E. J. Newman, 324 W. Yakima Ave. GL 2-9825

WEST VIRGINIA

FAIRMONT
Fairmont Amateur Astronomers Ass'n., Inc. †
D. Brown, 1255 Fennimore St. 629
WHEELING
Oglebay Inst. Astronomical Ass'n. *
R. W. Schramm, Speidel Obs., Oglebay Inst. WO 2125

WISCONSIN

BELOIT
Beloit Astronomical Society *†
Dr. K. E. Patterson, 304 Public Service Bldg. EM 5-7662
MADISON
Madison Astronomical Society †°
Dr. C. M. Huffer, Washburn Obs., Univ. of Wisconsin. AL 5-3311, ext. 2551
MILWAUKEE
Milwaukee Astronomical Society *†
E. Halbach, 2971 S. 52nd St. LI 1-1181
OSHKOSH
Fox River Valley Amateur Astronomers Club *†
J. H. Wojahn, 250 Lark St. BL 8171
RACINE
Racine Astronomical Society
Mrs. P. B. Carey, 1806½ Clayton Ave. ME 2-2278
SHEBOYGAN
Sheboygan Astronomical Society
E. Parnitzke, Jr., Rte. 2.

WYOMING

CHEYENNE
Cheyenne Amateur Astronomers *†
Mrs. P. Doran, 2706 E. 10th St. 2-3910

ASTRONOMICAL GROUPS IN INDUSTRY

Amateur astronomy clubs have been formed in two manufacturing companies. At Great Neck, New York, the Sperry Telescope and Astronomy Group was organized by 16 employees of the Sperry Gyroscope Co. Lloyed R. Kimball, 10 Woodwaye Rd., Plainview, N. Y., is chairman of the club.

Organized last October, the Astronomical Society for Convair, Ft. Worth, Texas, presently has 72 family units registered as members. Donald F. Hennrick, 5328 Whitten St., Ft. Worth 15, Tex., is program director.

HONOLULU, HAWAII

The former Honolulu Astronomical Society was reorganized by a group of amateurs last February and renamed the Hawaiian Astronomical Society. Earle G. Linsley, formerly director of the Chabot Observatory, Oakland, California, was designated president pro tem. Further information may be secured from him at the Bernice P. Bishop Museum, Honolulu 17, Hawaii.

Amateur Astronomers

MIDDLE EAST CONVENTION HELD IN HARRISBURG

SOME 80 participants representing seven societies in the Middle East Region of the Astronomical League attended the day-long meeting at the Paxton Presbyterian Church, Harrisburg, Pennsylvania, on June 8th.

Following a session for business, three members of the Astronomical Society of Harrisburg gave talks: George B. Schriver, "Concepts of the Universe"; Charles Keller, Jr., "Amateur Observations of the Planets Mars, Saturn, and Jupiter"; Donald Neidig, "Comets, Their Orbits and Composition."

At the round-table discussion, Leo N. Schoenig told how the Amateur Astronomers Association of Pittsburgh held a successful star party for 3,000 persons at the Allegheny Observatory. Charles S. Johnson, Detroit, Michigan, reported on an afternoon observing session of Venus, given by the juniors of the Detroit Astronomical Society in front of the city hall, which was attended by many city officials as well as the public.

The satellite-tracking session was highlighted by film slides of the stations set up by the different societies. The Philadelphia station, which is located on the roof of the Franklin Institute, has two meridian masts. Another variation was introduced by the station at Pennsylvania State University, which has a television antenna instead of a crossbar on the meridian mast.

At the convention dinner, Dr. Julian Ripley, of Dickinson College, described many theories and speculations on the origin of the universe.

The following regional officers were elected: Dana Law, Washington, D. C., chairman; R. Thomas LuCaric, Baden, Pennsylvania, vice-chairman; Elizabeth Byer, Philadelphia, secretary; Emil Klein, Philadelphia, treasurer; and Herbert N. Williams, Yorklyn, Delaware, regional representative. The 1958 meeting will be held in Fairmont, West Virginia.

MRS. TOVE NEVILLE
5006 Russell Rd.
Alexandria, Va.

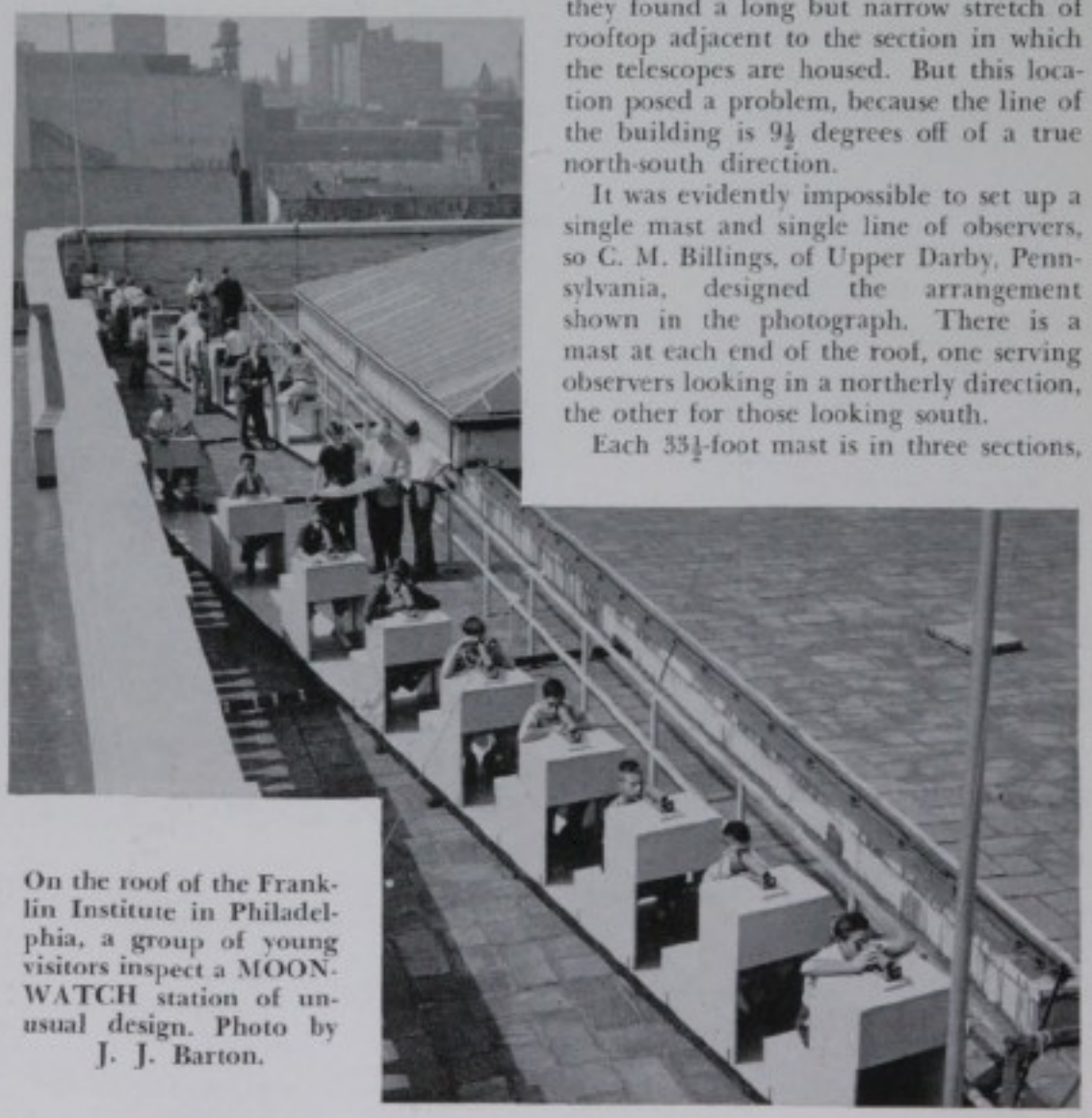
PHILADELPHIA MOONWATCH

VISITORS to the Franklin Institute in Philadelphia, where the Fels Planetarium is located, often have the opportunity to observe through two telescopes permanently mounted on the roof of the building. They are a 10-inch refractor and a 24-inch reflector, suitably arranged for public observing.

When the amateur astronomers at the Franklin Institute were looking for a place to set up a satellite-tracking station, they found a long but narrow stretch of rooftop adjacent to the section in which the telescopes are housed. But this location posed a problem, because the line of the building is 9½ degrees off of a true north-south direction.

It was evidently impossible to set up a single mast and single line of observers, so C. M. Billings, of Upper Darby, Pennsylvania, designed the arrangement shown in the photograph. There is a mast at each end of the roof, one serving observers looking in a northerly direction, the other for those looking south.

Each 33½-foot mast is in three sections,



On the roof of the Franklin Institute in Philadelphia, a group of young visitors inspect a MOONWATCH station of unusual design. Photo by J. J. Barton.

tapering from a 3-inch pipe at the bottom to a 2-inch one at the top. The cross pipes are each five feet long, set in a tee at the top of each mast and marking the north-south line. The masts are wired with lights, but these are used only occasionally for station inspection.

Each observer's desk is 24 inches wide, 17 inches deep, and 35 inches high from the platform floor. The attached benches have three different heights, 12, 18, and 24 inches, to accommodate variation in the angle setting of the telescopes. There are 18 desks in all, insuring observation of the meridian to within 30 degrees of each horizon. The fields overlap, complete coverage being obtained for a meridian strip 127½ degrees long and 8½ degrees wide.

All of the standard MOONWATCH telescopes are permanently mounted and adjusted on plywood boards, the station leader alone being responsible for any change of adjustment. The boards are numbered to correspond to the desks, so all the instruments may be kept indoors between sessions, yet accurately positioned whenever observing is resumed.

The recording equipment, which will be set on a table midway along the roof, includes a short-wave receiver, a tape recorder, a mixer, and microphones.

All construction and materials for the station setup were furnished by the City of Philadelphia, and the telescopes by the Seven-Up Bottling Co. of Philadelphia. Mr. Billings and Edwin F. Bailey, captain of the station, supervised the erection, which was completed in June.

GREAT PLAINS PUBLICATIONS

The Great Plains Astronomical Society prints three publications: *Thru the Eyepiece*, edited by Bill Bailey; the *Great Plains Observer*, edited by Walter Scott Houston; and the *Solar Division Bulletin*, by the undersigned. We would be pleased to exchange these periodicals with other amateur publications.

DALE P. CRUIKSHANK
3655 67th St.
Des Moines 10, Iowa

RAPID CITY, SOUTH DAKOTA

The Rapid City Astronomical Society meets on the second Saturday of each month in the new chemistry building of the South Dakota School of Mines and Technology. Our current activities include regular sunspot and northern lights observations, as well as participation in the observatory building program of the Rapid City Astronomical Foundation, Inc.

The foundation, a nonprofit corporation, was formed by several members of the society. It is currently raising funds to construct an observatory at the school.

JOHN C. SEARLE
P. O. Box 827
Rapid City, S. D.

THIS MONTH'S MEETINGS

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Sept. 7, Soren W. Henriksen, U. S. Army Map Service, "The Role of Astronomy in Geodesy."

SOUTH BEND, INDIANA

After two years of inactivity, the St. Joseph Valley Astronomical Society was reorganized last year during the close approach of Mars. Since that time, we have met informally at the homes of members once each month.

Our club is composed of 40 members, of whom about 15 are juniors. There are more than 20 telescopes in use, the largest being a 10-inch reflector and a 4-inch refractor. We publish a monthly bulletin which carries society news and astronomical puzzles.

BOB BARGMEYER
R.R. 6, 59587 S. Ironwood Rd.
South Bend 14, Ind.

ALBANY, NEW YORK

The Albany Astronomical Association meets on the second and fourth Monday of each month at the Dudley Observatory. The society is a member of the Astronomical League. More information may be had from Andrew L. Swider, 42 Hanes St., Albany 3, N. Y.

HOUSTON, TEXAS

A course of informal lectures for new and more experienced members is being offered at regular intervals by the Houston Amateur Astronomy Club. Upon completion of the series, each student is awarded a certificate denoting him a bona fide "amateur astronomer." C. Edward Forsythe, of the Houston club, is conductor of the course.

BOISE, IDAHO

On December 8, 1956, the Boise Astronomical Association was formed, and since that time the group has held meetings every other Saturday of the month. Its members are presently completing an 8-inch reflector to be shared by the group. Officers are Tom Cochrane, president; Herbert Richards, vice-president; and Linda Moulton, secretary-treasurer. Further information may be had from Miss Moulton, 1712 N. 28th, Boise, Idaho.

NEW YORK AMATEURS

George V. Plachy, secretary of the Amateur Astronomers Association of New York City for the past 17 years, has retired from his position. At the society's 30th anniversary dinner in May, it was announced that Mrs. Antoinette Pridmore is now the secretary for the largest amateur society in the country.

More than 100 members and guests attended the dinner. The feature speaker was Dr. J. Allen Hynek, Smithsonian Astrophysical Observatory, who told of the many problems and phases in setting up a world-wide satellite-tracking program. Dr. Jan Schilt, director of Rutherfurd Observatory, presented the Amateur Astronomers medal, which this year was awarded to the well-known French astronomer, Mme. G. Camille Flammarion, and to James W. Gagan, of the Amateur Telescope Makers of Boston.

A TELESCOPE FOR SATELLITE VERIFICATION

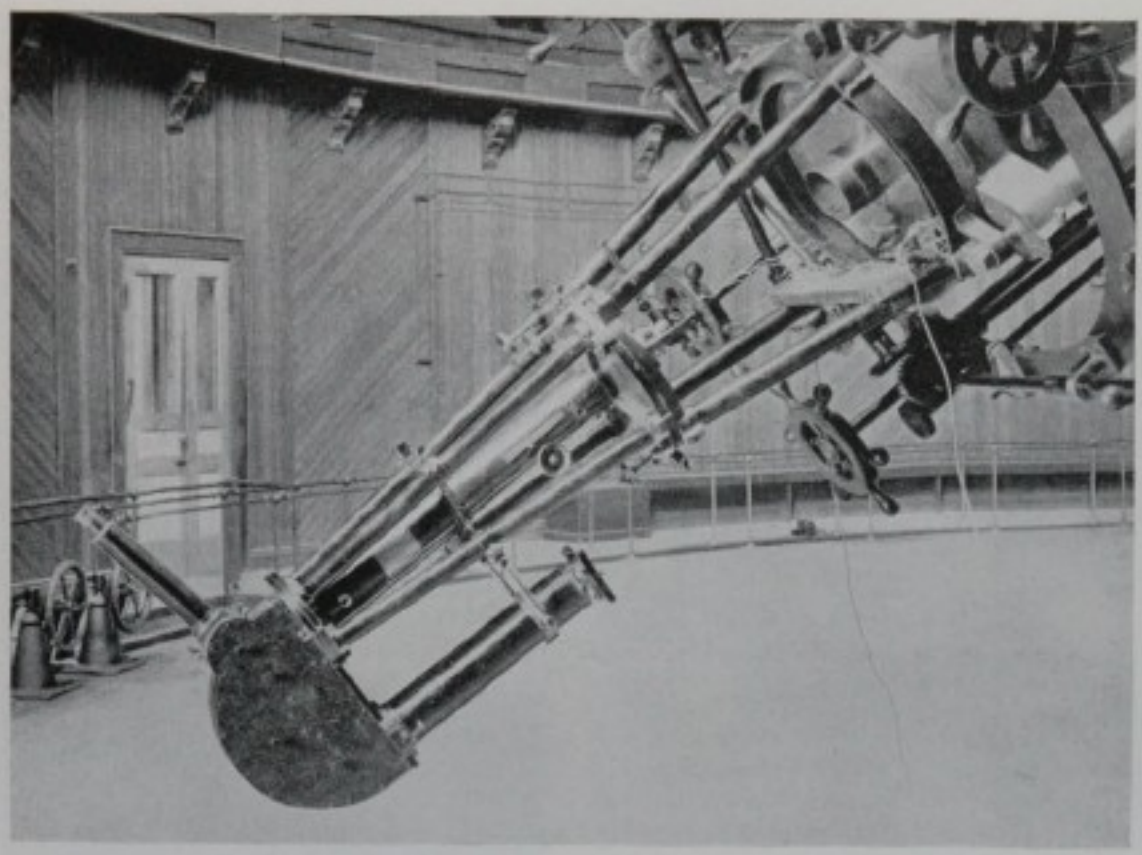
Team leaders of the MOONWATCH program will find useful a telescope of the kind shown here. When tried out at a special alert for the Washington, D. C., area recently it worked rather well. As soon as an observer announced a

The mounting of Mr. Wright's spotting telescope has three degrees of freedom. The instrument is intended for checking MOONWATCH sightings.

sighting the instrument could be swung over to that part of the sky and the flyby picked up.

An M6 war-surplus elbow telescope was used; it has an 8½-degree field and 8x magnification. The mounting is similar to the one designed for the 20-inch Baker-Nunn satellite cameras (*Sky and Telescope*, January, 1957, page 108). There are three movements that permit rapid pointing and tracking: 1. The fork rotates in azimuth. 2. The telescope assembly moves in altitude on the horizontal axis at the top of the fork. 3. The telescope rotates on an axis that extends from the base of the prism housing—the rotation is around the eyepiece.

G. R. WRIGHT
202 Piping Rock Drive
Silver Spring, Md.



The original Mills spectrograph attached to the 36-inch refractor of Lick Observatory, as it appeared in 1896. The three prisms deviate the starlight a full 180 degrees, so the plateholder is at the upper end of the tube in the lower center of the picture. Reproduced from "Publications" of Lick Observatory.

Stellar Spectrographs—I

OTTO STRUVE, *Leuschner Observatory, University of California*

ASTROPHYSICS as a major branch of astronomy owes its development to the spectrograph, the most important accessory to the telescope that we have used in recent decades. The principle of a stellar spectrograph is simple, but not its construction. The days are long past when it was possible to pick out, almost at random, a pair of lenses and a prism, and readily mount them on a suitable supporting frame, with a slit in front of the collimator lens and a plateholder in the focal plane of the camera lens.

To build efficient and powerful stellar spectrographs now demands a combination of optical knowledge, engineering skill, and intuition unparalleled in other fields of astronomical instrument making. Moreover, the designer must know exactly what the problems are that the astrophysicist wishes to solve, in order to provide the best possible spectrograph for the work.

The first requirement in stellar spectroscopy is adequate *resolving power*. This term designates the inverse ratio of the smallest visible separation of two neighboring spectral lines to their average wave length, that is, $\lambda/\triangle\lambda$, where λ stands for wave length. For instance, a spectrograph that just resolves the well-known pair of yellow sodium lines, at 5896 and 5890 angstroms, has a resolving power of about 5893/(5896 – 5890), or about 1,000.

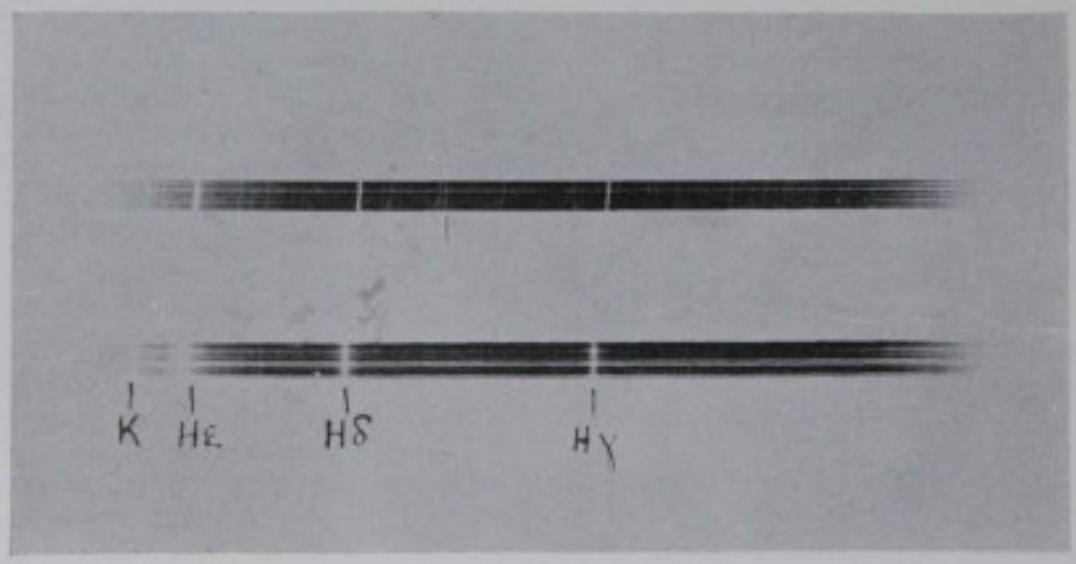
A spectrograph may have for its dispersing element a prism or a grating. In the first case the light passes through the prism and is dispersed because shorter wave lengths are refracted more than longer ones; in the second case, the light is dispersed by the phenomenon of diffraction, either while passing through the lines of the grating or while being reflected from them. To obtain high dispersion with prisms, several of them may be used in tandem. Gratings give spectra of different orders, the dispersion being greater the higher the order.

To determine the resolving power of a prism, measure the length of its base, the side parallel to the average direction in which the light passes through the prism. Then the resolving power is the product of the prism's base length and the change in the refractive index of the glass per unit of wave length. If, for example, the index of refraction at λ6563 is 1.486012 and at λ5607 it is 1.489187, the average change in index is 0.003175 for 956 angstrom units. Each angstrom is 10^{-8} centimeter; hence, the change in index is about 332 per centimeter of prism base. Therefore, a prism base of three centimeters would give a resolving power of about 1,000 with this index change, splitting the sodium pair. Actually, the change in refractive index at λ5893 is somewhat larger, for most glasses, and a prism with a base of about 2.7 centimeters will suffice to resolve the sodium lines.

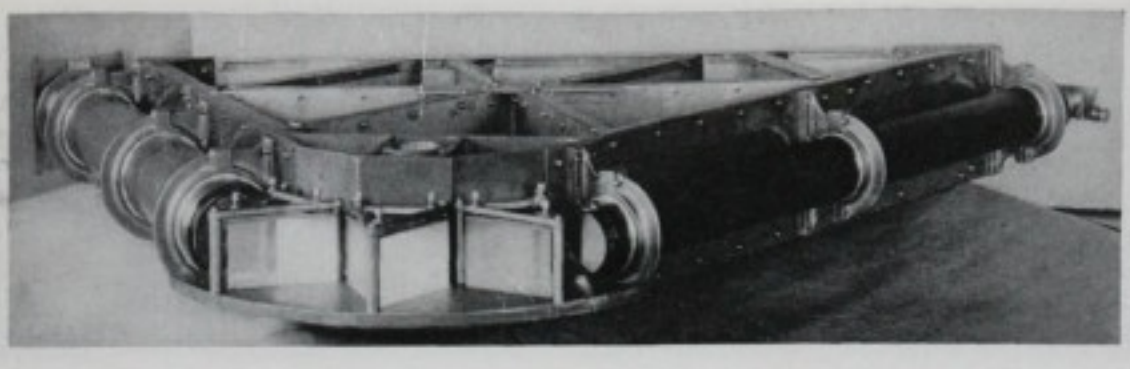
If a diffraction grating is used, the expression for resolving power is especially simple. It is the product of N, the total number of grooves on the grating, and m, the order of the spectrum observed. To resolve the sodium pair in the first order ($m = 1$), N must be 1,000. If a ruling engine for a grating makes 20,000 lines to the inch, a ruled surface 1/20 of an inch wide would be sufficient to split the sodium pair. In several modern spectrographs of this quality, the ruled surfaces are six inches in size. Hence, their resolving power is of the order of 20,000 $\times$ 6 = 120,000 in the first order, and 240,000 in the second order.

In order to obtain a resolving power of 100,000 at the sodium lines, that is, to resolve two lines 0.06 angstrom apart, a prism base of 270 centimeters would be required. This cannot be achieved with a single prism, but could be with many large prisms placed in succession.

The present status of the problems of



Seventy years ago, on September 8, 1887, these spectra of Deneb (upper) and Altair were taken with a spectrograph of four prisms attached to the 11-inch Draper refractor of Harvard College Observatory. The K line of calcium and some hydrogen lines are marked.



A three-prism spectrograph of typical design, shown with its constant-temperature jacket removed. The slit and collimator are seen at the right; the camera and plateholder are at the left.

spectrograph construction has been reviewed in *Vistas in Astronomy* by the two astronomers who have made the greatest contributions in this field during the present generation. I. S. Bowen writes on "Astronomical Spectrographs: Past, Present and Future" (Vol. 1, page 400), and Theodore Dunham, Jr., discusses "Methods in Stellar Spectroscopy" (Vol. 2, page 1223). (Volume 2 of *Vistas* is reviewed on page 542 of this issue.)

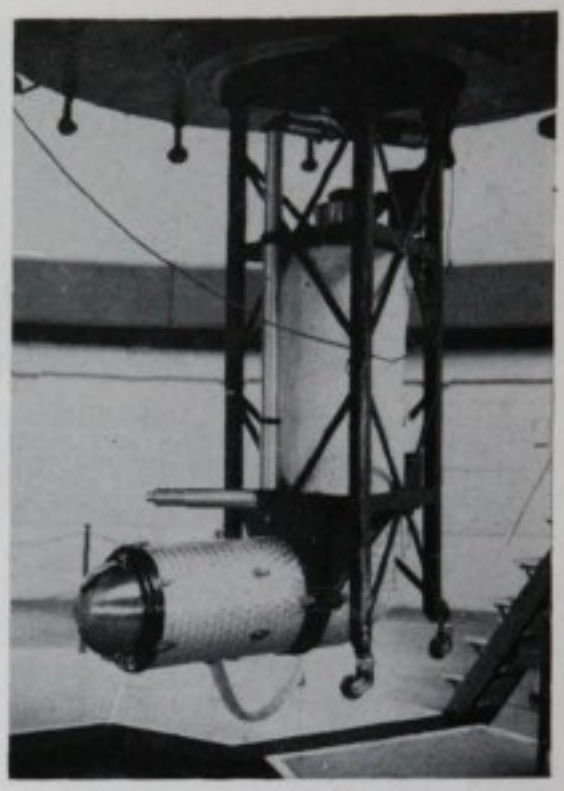
In his article, Dunham recognizes four "clearly defined stages in the development of stellar spectroscopy":

1. The first stage started with Fraunhofer's pioneering observations 1½ centuries ago, and included the visual instruments of Secchi and Huggins with resolving powers of about 1,000. Their work led to the discovery that the chemical elements in the stars are the same as those found on the earth.

2. In 1863 Huggins and Miller started to photograph stellar spectra, and Henry Draper, by 1879, had obtained a resolving power of about 5,000.

3. In the 1890's and the first few decades of the 20th century, many powerful prism spectrographs were constructed, at Potsdam, Lick, Yerkes, Lowell, Poulkovo, Mount Wilson, Dominion Astrophysical, and other observatories. The best among the older of these instruments was probably the three-prism Mills spectrograph of the Lick Observatory, constructed by W. W. Campbell, with an effective resolving power of 30,000 or better. The principal results obtained with these instruments were determinations of the line-of-sight motions of thousands of stars from measurements of the Doppler displacements of their spectral lines.

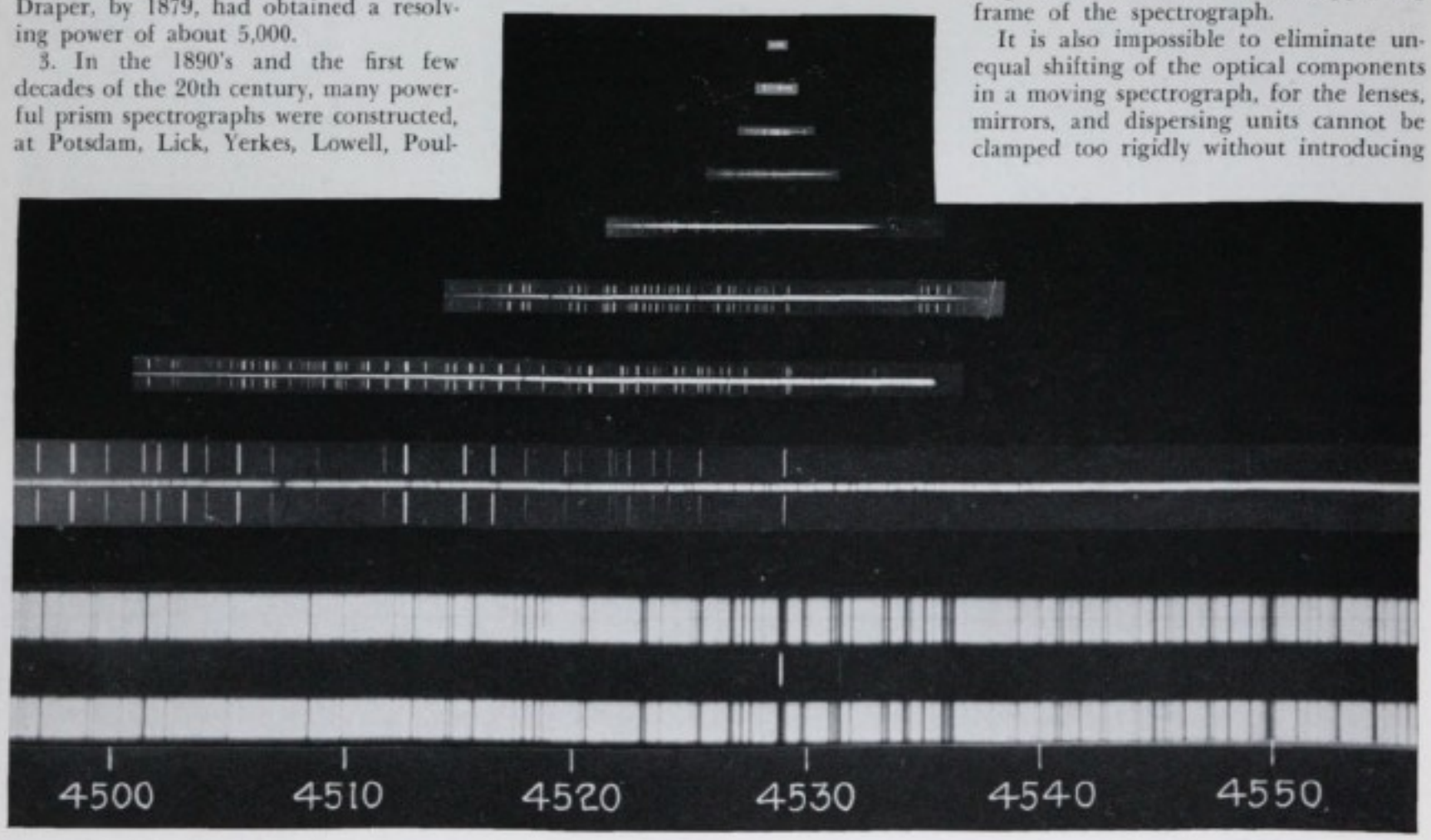
4. This stage began in 1911, when W. S. Adams installed a powerful stationary spectrograph at the coude focus of the 60-inch telescope at Mount Wilson Observatory. A plane mirror placed behind a very large Schott glass prism caused the light from the star being observed to pass twice through the prism. The resolving power was about 70,000, and the linear dispersion 1.4 angstroms per millimeter.



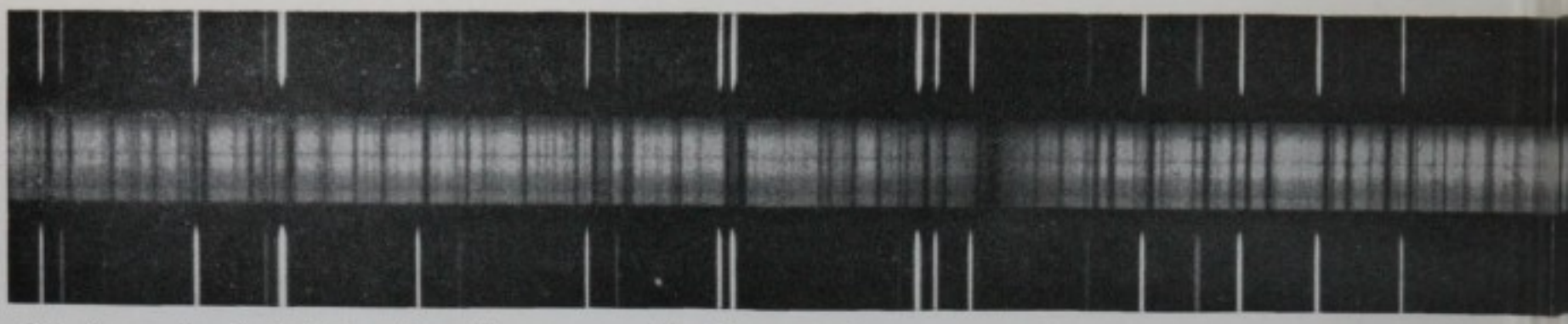
Starlight is deflected 90 degrees while passing through a pair of prisms in this spectrograph at the Cassegrainian focus of the 82-inch reflector at McDonald Observatory.

A stationary spectrograph of this kind was a radical departure from most previous installations, which consisted of relatively small instruments attached at the lower end of a refractor or at the Cassegrainian focus of a reflector. Such a spectrograph moves with the telescope during the exposure and is subject to differential flexure, not only of the telescope tube but of the entire supporting frame of the spectrograph.

It is also impossible to eliminate unequal shifting of the optical components in a moving spectrograph, for the lenses, mirrors, and dispersing units cannot be clamped too rigidly without introducing



A chart of spectra from Mount Wilson Observatory to illustrate the effect of increased dispersion on the visibility of details. The actual spectra have dispersions ranging from 835 to 0.7 angstroms per millimeter, being here enlarged over two times. In the lowest spectrum the reproduced scale is about three millimeters to one angstrom.



This is a portion of the violet region of the spectrum of the 1st-magnitude star Procyon, from a spectrogram taken by Otto Struve with the coude spectrograph of the 100-inch telescope at Mount Wilson Observatory. He used the 114-inch camera, giving a scale of 2.9 angstroms per millimeter on the original negative. This reproduction, enlarged about nine times, is a positive, the absorption lines produced in the star's atmosphere appearing dark on the bright continuous back-

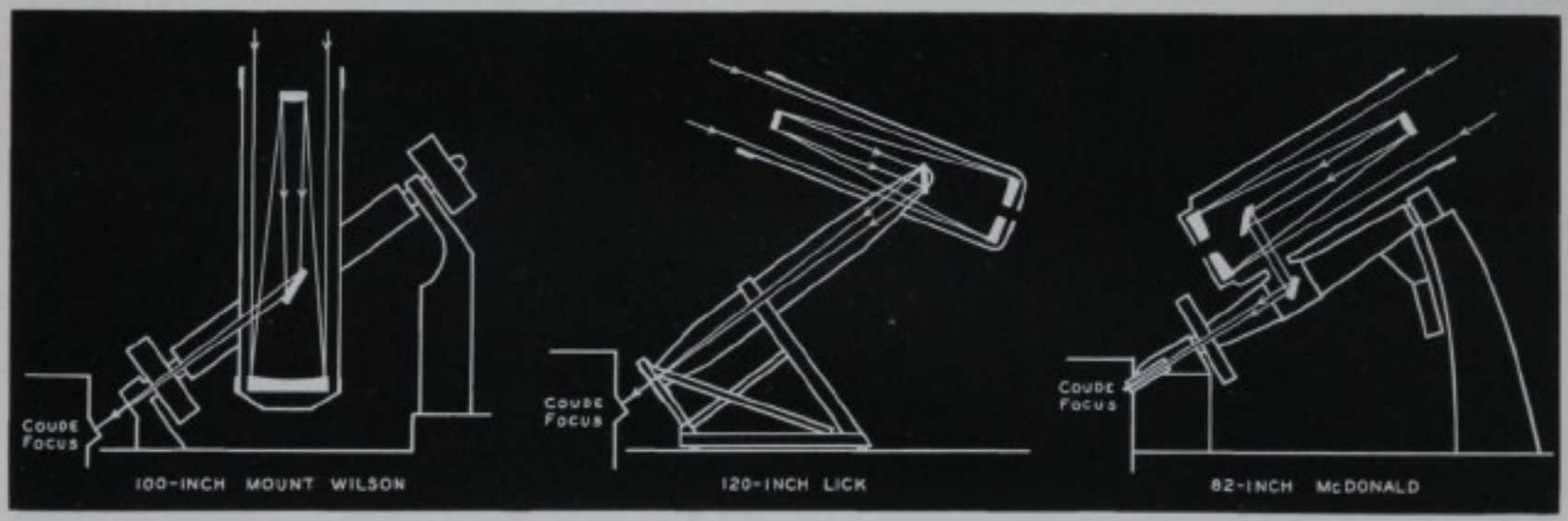
optical distortion. Yet if they are held a bit loosely, they may be slightly displaced as the hour angle changes during the exposure, and this may lead to appreciable errors in the measurement of the spectral lines.

Development of stellar spectrographs is at present mainly concerned with large stationary instruments at the coude foci of powerful reflecting telescopes. Several important improvements have been made in recent years, such as the invention of the Schmidt-type camera, which can be adapted to the spectrograph with a wide range in focal ratios.

The aluminizing process for astronomical mirrors has been applied to the optical parts of the spectrograph; nearly all modern instruments use aluminized paraboloidal mirrors as collimators. Furthermore, large plane gratings ruled on aluminized glass disks were found to be more efficient than the old gratings ruled on speculum metal.

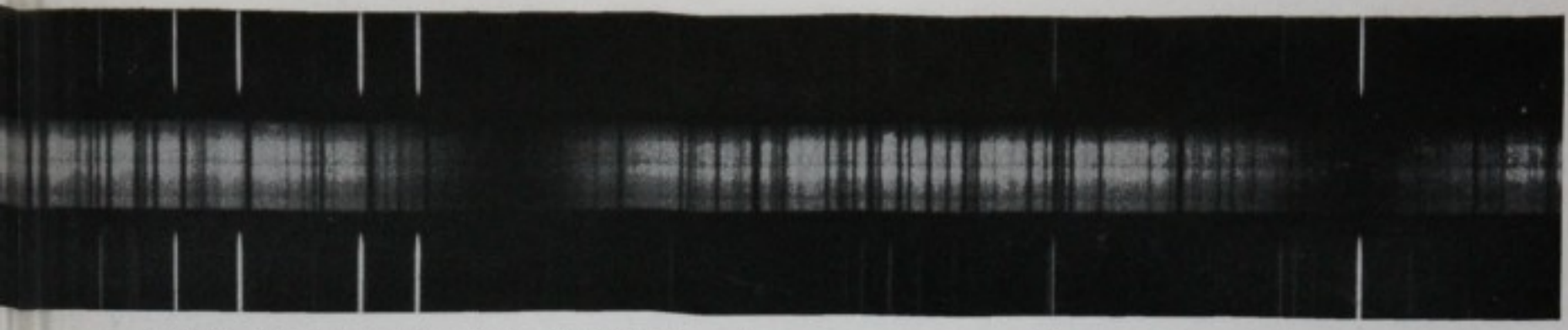
Proper shaping of the diamond tool of the ruling engine has permitted *blazing* the grating to concentrate the light into any chosen order on one side of the central image. This overcomes one of the disadvantages of diffraction gratings, their waste of light. Therefore, modern gratings are far more efficient as dispersing units than are glass prisms. Nearly all modern spectrographs use gratings.

The coude optical arrangement is sketched in the accompanying diagrams, one for a mounting of the fork type, such as the Lick 120-inch, another for a yoke or cradle mounting, such as the 100-inch and 200-inch reflectors of Mount Wilson and Palomar Observatories, and the third for the McDonald 82-inch. The secondary mirror is made hyperboloidal, and increases the focal ratio many times, to about f/30. Except for observations in the circumpolar regions, the fork and yoke mountings require only one plane mirror to direct the light down the polar



The path of starlight (indicated by the arrows) to the coude focus in the spectrograph room of each of three large reflectors is shown by these sketches. The 100-inch at Mount Wilson Observatory has a two-pier yoke or cradle mounting, and the 120-inch at Lick Observatory is mounted in a fork. The 82-inch McDonald Observatory mounting is of the cross-axis type, and while two coude mirrors are always required, they are at 45-degree angles to the optical axis regardless of the part of the sky to which the reflector is pointed.

With the 100-inch coude spectrograph, Otto Struve also made this spectrogram of the 1st-magnitude star Arcturus. This is an orange giant of spectral type K2, while Procyon is a hotter, yellow main-sequence star of type F5. Because the atmosphere of Arcturus is cooler than Procyon's, its spectrum has many additional lines, predominantly of neutral metallic atoms. Molecular absorption bands also appear, a good example of a band head occurring in the array of tightly packed



ground. The bright lines above and below the stellar spectrum are from a laboratory source of the element iron. Note how the absorption lines of iron in the star's spectrum are all shifted to the right (redward) of the corresponding comparison lines, a consequence of the relative motion of recession of the earth and Procyon at the time the spectrum was made. The photographs on this page are courtesy Mount Wilson and Palomar Observatories.

axis to the spectrograph room at its southern end. There the spectrograph instruments can be permanently mounted and the temperature kept constant to a fraction of a degree.

The optical arrangement for the coude spectrograph of the 100-inch telescope, as set up in 1939, is shown by the diagram on this page adapted from Dunham's article in *Vistas*. Some additional arrangements are possible, but the astronomer has principally the choice of three plate scales to suit the observing problem at hand. For large scale, he can use the 114-inch camera with a 36-inch spherical mirror, obtaining high-dispersion pictures of bright-star spectra, like those of Arcturus and Procyon reproduced here.

Two Schmidt cameras, giving brighter spectra at lower dispersions, are mounted horizontally, in such a way that the mirror of short focus can be moved from in front of the longer one, the correcting plates being interchangeable. The photographic speed of the 32-inch Schmidt is over 12 times that of the 114-inch spherical-mirror system. On the other hand, the dispersion with the 32-inch is 10.4 angstroms per millimeter in the second order (at 4000 angstroms), whereas with the 114-inch it is 2.9 angstroms per millimeter. Dunham points out that on bright stars this long camera has achieved an effective resolving power of about 100,000.

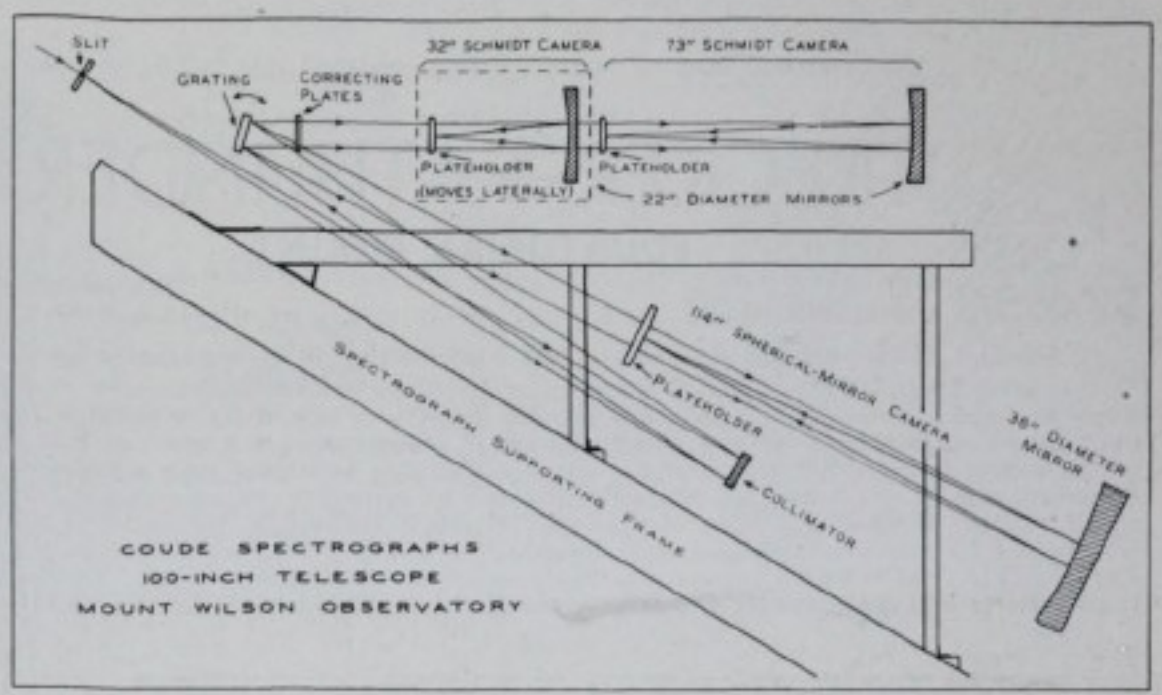
He goes on to say, however, that undue emphasis has perhaps been placed on the high dispersion of coude systems, and continues:

"The possibility of using very large prism or grating apertures is the basic advantage of the coudé instrument, because this greatly increases the efficiency of the spectrograph for both high and low dispersion. As a consequence, the duration of exposures is reduced, and fainter stars come within the range of the instrument. . . . Only when extremely faint objects are photographed, necessarily at very low dispersion, with a telescope of small or moderate size, can a Cassegrain or direct-focus spectrograph with small-aperture optical elements equal the efficiency of a coudé spectrograph.

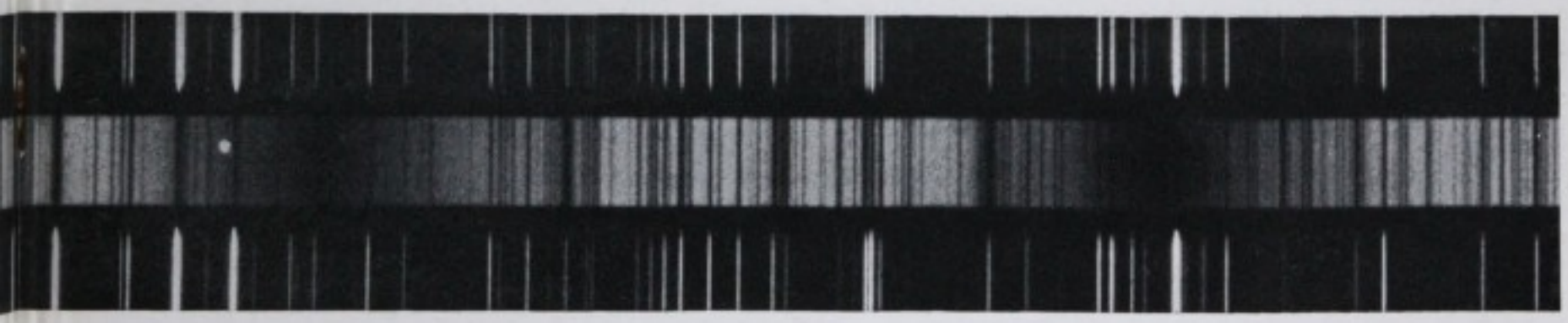
"The large coudé instruments have made possible accurate quantitative work in several fields, including the measurement of radial velocities for individual elements, integrated intensities of absorption lines, chemical abundances and ionization ratios. New interstellar elements and molecules have been detected and individual clouds of interstellar material have been recognized. Several gaseous components of planetary atmospheres have been identified, and magnetic fields have been discovered in many stars."

In the second part of this article, we shall discuss some further factors affecting spectrograph design.

(To be continued)



This diagram is adapted from one by Theodore Dunham, Jr., to show the 100-inch telescope's coude spectrograph arrangement.



lines some three inches from the left end of the spectrum. The most conspicuous features in the right-hand portion of each star's spectrum are two intense and extremely broad absorptions, the well-known H and K lines of singly ionized calcium. The H line is farther to the right, at a wave length of 3968.5 angstroms; the K line is at 3933.7 angstroms. These two lines are also very prominent in the spectrum of the sun.

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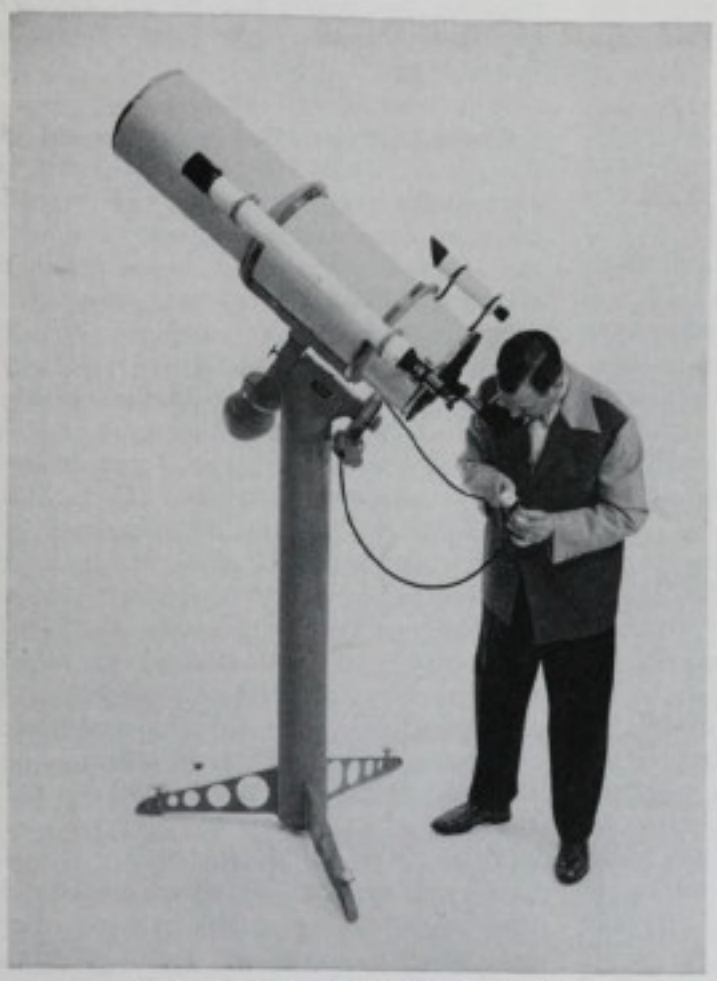

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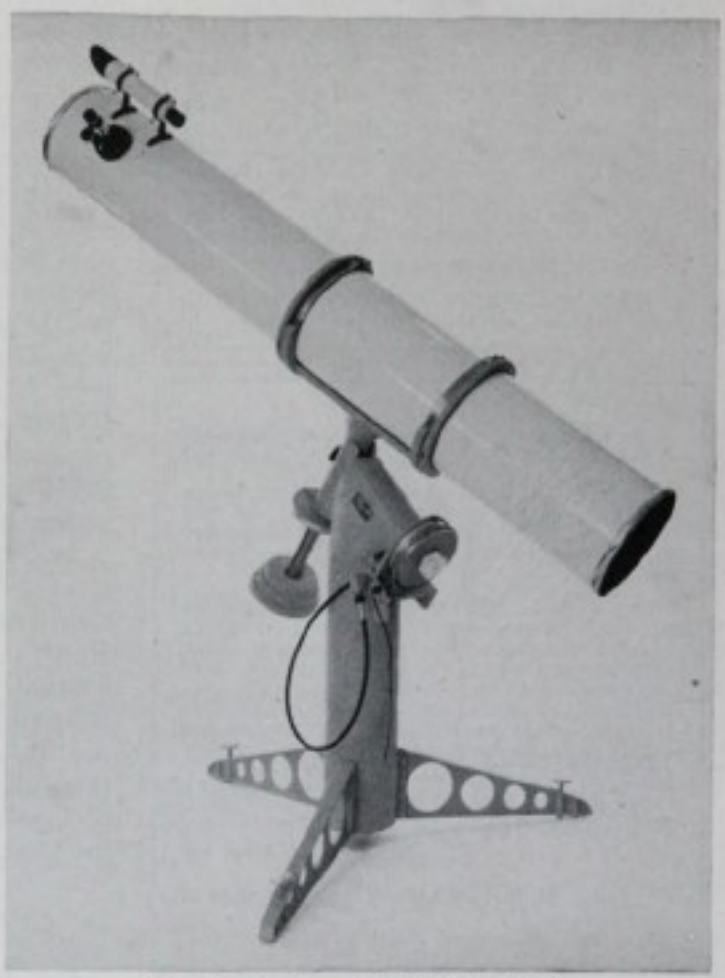

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BOOKS AND THE SKY

VISTAS IN ASTRONOMY
Volume 2

Arthur Beer, editor. Pergamon Press, London, 1956. (Western Hemisphere distributors, Sky Publishing Corporation, Cambridge, Mass.) 994 pages. $44.00.

THERE ARE two things obviously wrong with this otherwise very stimulating and voluminous book. First, the price is such that few astronomers will be able to afford a personal copy, and many libraries that should order this book will not do so because they have limited budgets. The price per equivalent page, however, is comparable with that of recent astronomical books. Second, most of the papers were evidently written in 1952 or 1953, and a four-year publication delay is unfortunate.

Among the papers which, because of recent developments, would be significantly modified if written today are S. F. Singer's on high-altitude rockets; the fluctuations of the earth's rotation, by the Brussels astronomers; W. J. Luyten's on the white dwarfs; the photometry of the Hyades, by O. Heckmann; the spectrum of Algol, by O. Struve; W. H. Ramsey's on the Crab nebula; an analysis of the Milky Way, by W. Becker; and the problem of extragalactic red shifts, by M. L. Humason.

Nevertheless, like its predecessor, Volume 1, this book should be considered required reading for researchers, college teachers, and graduate students in astronomy. If this review does nothing more than inspire a number of graduate students to read carefully the two volumes of *Vistas in Astronomy*, then it will have served its purpose. These works should also be of considerable interest to advanced amateur astronomers and to professionals in the allied fields of geophysics and physics.

The 215 authors have provided an authority and a vitality that should appeal to every astronomer—the vistas they present are indeed exciting. In fact, the success of these two Stratton memorial volumes has been so remarkable that it is planned to publish *Vistas* as an annual review, starting in 1958.

There is a real need for such a publication, if only to present to American astronomers (in English) the important results and conclusions of astronomers in France, Germany, and Russia. At the same time, it is hoped that young Americans, such as Arp, Baum, Herbig, H. L. Johnson, Meinel, Miss Roman, Sandage, Walker, and others who have made important contributions in the past few years, may be given an opportunity to present syntheses of their researches.

Volume 2 is a five-pound tome containing 99 papers arranged into nine sections: Solar-Terrestrial Relations, Geophysics, Planetary System, Stellar Astronomy, Photometry, Spectroscopy, Spectral Peculiarities and Novae, Galaxies, Cosmogony and Cosmology. This book also contains the name and subject indexes for both volumes. More than 10 days of full-time reading will be required to go over Volume 2 even once lightly.

Despite the fact that only one out of five of the authors is from this country, both books indicate a surprisingly healthy state of American astronomy, and also strikingly illustrate the importance of observations with great reflectors. For example, suppose we consider the 40 astronomers whose work is important enough to be referred to in the index a dozen or more times. This somewhat arbitrary criterion includes Tycho Brahe, but excludes such notables as G. Galilei, J. Kepler, I. Newton, W. Herschel, A. Einstein, and several past presidents of the International Astronomical Union. It turns out that 60 per cent of the 40 astronomers so distinguished are from this country; furthermore, two-thirds of the American group have worked more than casually with the great reflectors on Palomar Mountain, Mt. Wilson, or Mt. Locke.

G. Shajn, E. R. Mustel, and V. A. Ambarzumian are the only representatives of Russian astronomy in this volume. The contrasting evolutionary points of view of the English "accretionists" and Ambarzumian are especially noteworthy. The latter writes:

"In our studies of stellar associations we concluded that the formation of stars is going on in the present state of our Galaxy. . . . It is obvious now that stars are, as a rule, originating in groups and within comparatively small volumes."

On the other side of the picture, R. A. Lyttleton states:

"To explain more fully the difficulty of the brightest stars: the argument was that even supposing that they were 'born only yesterday,' their future ages could be but a small fraction of the accepted age of the universe, and hence that such stars must be of recent origin. This last inference seemed impossible to accept. . . . Since the energy required for them to have an adequate age is not *in* the brightest stars, it must lie *outside*, and some process must operate to bring it in."

My own feeling is that our knowledge of stellar evolution has worked its way up from absolutely nothing—or perhaps, as P. W. Merrill has put it, less than nothing—to extreme poverty. The next few years should yield substantial progress is this difficult field, by means of detailed electronic calculations of stellar models based on improved physical knowledge. Advances will also result especially from photoelectric observations of both galactic clusters, where the mass-luminosity law probably holds, and of

globular clusters, where it almost certainly does not.

In the southern hemisphere of the sky —so rich in both types of clusters—however, the *immediate* observational prospects for such work are not very encouraging. The southern telescopes are much too few, often poorly located and committed to other programs, and there are no really large reflectors. Furthermore, there are still no adequate southern photoelectric standards; an extension of the Johnson-Morgan system, especially in the ultraviolet, is a prime necessity and would require only a modest aluminized reflector in a good location.

Spectroscopic and astrometric observations of clusters and double stars are also of great importance in the problem of stellar evolution. The astrometric situation is somewhat discouraging. Our present knowledge of stellar evolution would be of an entirely different order of magnitude had we proper motions 10 to 100 times more accurate than those presently obtainable. We ought now to observe the *positions* of hundreds of thousands of stars as accurately as we know how, so that future astronomers *will* have the proper-motion material that we would so much like to have today. I am not convinced that the astrometric instruments now in use are the best we can make. For example, the wide-angle cameras used at Yale, at the Cape, and in the AGK2 program have focal lengths much too short for high precision.

The section of *Vistas* on galaxies is perhaps the most stimulating of all. Astronomical texts in general do not give adequate treatments of this subject. Yet even here, Humason's discussion of red shifts is the only one of nine papers on galaxies that deals with the work of the biggest reflectors, although the Radcliffe Observatory photographs by D. S. Evans present a number of remarkable southern galaxies. Papers by W. Baade and F. Zwicky would have been most welcome in this section. Probably the best account of extragalactic researches at Palomar is still to be found in the mimeographed notes of the 1953 University of Michigan symposium, supplemented by Director I. S. Bowen's detailed annual reports of Mount Wilson and Palomar Observatories, which are published in the year books of the Carnegie Institution. (Incidentally, it is hoped that the long awaited Mount Wilson-Palomar photographs of northern galaxies will soon be published.)

The role of relatively small telescopes in extragalactic research is surprisingly important, as is well brought out in the papers of H. Shapley, C. D. Shane, and G. de Vaucouleurs. The significant and far-reaching Lick survey (*Sky and Telescope*, February, 1957, page 162) shows what can be done with a 20-inch telescope, good skies, and 5 or 10 years of counting fuzzy spots on plates. This work should soon be extended to the Southern Hemisphere, perhaps with better optics.

I found most convincing de Vaucouleurs' conclusion that we are near the edge of a flattened cluster of galaxies whose center is in the Virgo cluster. The analogy is strong; just as studies of single galaxies have helped us identify our galactic nucleus as being in the Sagittarius starclouds, so observations of clusters of galaxies strongly suggest our membership in such a cluster with its center in Virgo. Perhaps the day will come when we discuss with some confidence the constants of supergalactic rotation!

Three papers show that no longer are spectroscopic parallaxes to be determined with some confidence only for stars later than spectral type *A*. Excellent types and absolute magnitudes are derived by D. Chalonge from spectrogram tracings in and near the Balmer discontinuity, by B. Strömgren from photoelectric observations at hydrogen beta and in the ultraviolet, and by R. M. Petrie from microphotometer tracings giving the equivalent widths of the hydrogen-gamma line.

Such systematic differences as that of nearly a magnitude between Petrie's values and those of W. W. Morgan and P. C. Keenan should be resolved by more work on galactic clusters. A number of phototubes located at the coude focus of a reflector could measure quickly and efficiently narrow spectral regions centered on the lines of hydrogen, calcium, sodium, and other strong features.

The paper by W. W. Morgan and D. L. Harris shows how powerful photoelectric methods can be, given the proper calibration. Three-color observations of 23 stars in Messier 29 give a greatly improved distance to that galactic cluster, despite patchy obscuration in front of it averaging over three magnitudes of absorption—a patchiness later confirmed by W. A. Hiltner's polarization measures.

How photometric techniques have changed in the past few years is strikingly emphasized by comparison of later work with Heckmann's paper on the Hyades, which presents some of the best photographic photometry ever done. Heckmann obtains an average probable error of a color index of ±0.013 magnitude, derived from 67 plates taken with four different telescopes over a seven-year period. In contrast, Johnson and C. F. Knuckles photoelectrically observed twice as many cluster stars as did Heckmann, using a 20-inch reflector on 14 nights over a four-month period starting December, 1954.

Their paper was received by the *Astrophysical Journal* early in April, 1955! The probable error for a *single* observation in the B—V color index was only ±0.005 magnitude for ⅞ of their stars. Furthermore, their magnitudes and colors were placed directly and with confidence as to zero point, color, and scale, on a well-established system, with the further advantage that the important ultraviolet colors were measured. However, the *final* important conclusions as to fine structure in the color-magnitude array and the striking similarity of the Hyades cluster to the Praesepe cluster have only been made possible by combining the recently derived Bergedorf proper motions with the photoelectric results.

In a paper by A. Hunter and E. G. Martin, "Fifty Years of Trigonometrical Parallaxes," is a statement to which one can take exception. They say, "It is important to remember that it is these [photographic parallax] observations on which, in the last analysis, all estimates of celestial distance, galactic or extragalactic, are based."

This is an all-too-prevalent misconception. Extragalactic distances are fundamentally based on photometric observations of Cepheid variable stars, with the aid of the period-luminosity law; the same may be said for the distances to globular clusters and to the galactic center. The widely used zero-point correction, −1.4 ± 0.3 magnitudes, by A. Blaauw and H. R. Morgan, was derived from a

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discussion of the upsilon components of the proper motions of 18 Cepheids. This analysis depends on the amount and direction of the solar motion, which in turn is based on radial velocity observations and, to a limited extent, on proper motions; it has nothing to do with trigonometric parallaxes.

Despite the tremendous efforts put forth to derive high-quality trigonometric parallaxes for the Cepheids, they are useless in this problem both individually and when averaged for many stars. The trigonometric method scarcely plays the role of even a rough check on our extragalactic distance scale at the present time. We obviously need better such parallaxes, more especially for many faint nearby stars, such as the white dwarfs. My own vista in this field is the installation of modern, large, precisely lapped driving gears for all parallax telescopes; along with this we should have photoelectric guiding.

Other high points in Volume 2 include Hiltner's excellent review of interstellar polarization, a field to which he has contributed so much. The last paper by the late H. N. Russell is on four eclipsing stars in the Magellanic Clouds; he derives diameters for these stars, which are more than 150,000 light-years away, and shows their similarity to eclipsing systems in our own galaxy. Luyten's effective plea for more observations of white dwarfs has already been answered in part by the photoelectric work of Harris and the magnificent Palomar spectroscopy by J. L. Greenstein. Luyten's 100 or more white dwarfs south of declination −50°, however, are still almost completely untouched.

Singer's long and well-illustrated paper on research with high-altitude rockets has great general interest. A Viking rocket costs upwards of $400,000, and the artificial satellite program will probably run well over $50,000,000. I am strongly inclined to believe that the money might be used more profitably in support of our top scientists along more conventional lines — such sums put into astronomy would almost revolutionize it.

But an effectively operating space observatory would give us incredibly sharp star images, while stars and galaxies would be discovered and analyzed at far greater distances than they are now. The main advantage of such a space observatory, however, would probably be in the ultraviolet and at shorter wave lengths, where atomic and nuclear activity are so strong, which cannot now penetrate the earth's atmosphere. Some of this important information concerning the universe has been on its way millions and even billions of years, yet in a few microseconds it is absorbed and lost in the upper atmosphere.

The following quotes from Volume 2 are of special interest:

"With some certainty one can tell from the mere appearance of a comet in a telescope whether it is an old or a new object." *M. Beyer.*

"It appears from these studies that as many as 80 per cent of the stars may be binaries." *A. Beer.*

"The problem of the slow solar rotation is not unique; all old dwarf stars appear to have slow rotations. This result, in turn, seems to imply that nearly all main-sequence stars in their last stages of contraction developed the equivalent of a (small) solar nebula, to which they lost the bulk of their angular momentum. . . . On this basis, planetary systems would be even more common than was thought previously." *G. P. Kuiper.*

"It is concluded that with the exception of small Krakatoa-type explosive craters, all features of the Moon are directly and indirectly due to collisions of objects with the Moon's surface. The largest is estimated as having been 200 km in diameter." *H. C. Urey.*

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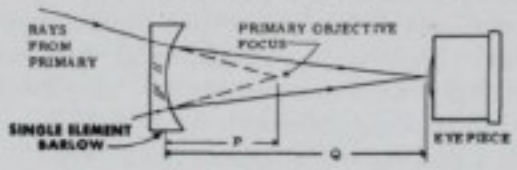
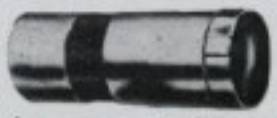


WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q!



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UTILIZING a doublet lens to correct the aberrations of a spherical mirror, the writer has designed and constructed a small f/8 telescope for visual use. The lens has considerable negative power, so that it serves as a Barlow lens as well as a corrector.

The lens is 2" in diameter, placed 6" inside the mirror's normal focal point. Extremely small star images are produced, and difficult double stars can be separated at surprisingly low power. With an Erfle eyepiece, images are sharp and colorless over a wide field.

Usually, the construction of an optically corrected, compact telescope presents some difficult problems for the amateur. Short-focus paraboloidal mirrors require increased accuracy of zonal measurements, as shown by this table for the conventional Foucault test:

Focal ratio of mirror, F/D	*Tolerable error of knife-edge reading, in inches*
f/3	0.006
f/4	0.010
f/6	0.023
f/8	0.041

For example, to verify the figure accuracy of an f/4 paraboloidal mirror of any diameter, the knife-edge setting must be read to 1/100 of an inch.

Even assuming that the spherical aberration of a short-focus mirror can be perfectly corrected, there is always the matter of off-axis aberrations, which increase rapidly as the focal length is reduced. An excellent discussion of these aberrations is contained in the article by James G. Baker in *Amateur Telescope Making—Book III*. The following table, adapted in part from Dr. Baker's article, gives the size of the field outside of which "the comatic flare becomes of such a size as to be apparent over the graininess of the [photographic] emulsion or larger than the seeing disk."

Focal ratio of mirror, F/D	*Diameter of good field, in inches*
f/3	0.36
f/4	0.64
f/6	1.44
f/8	2.56

Again, the dimension listed is independent of the absolute size of the instrument.

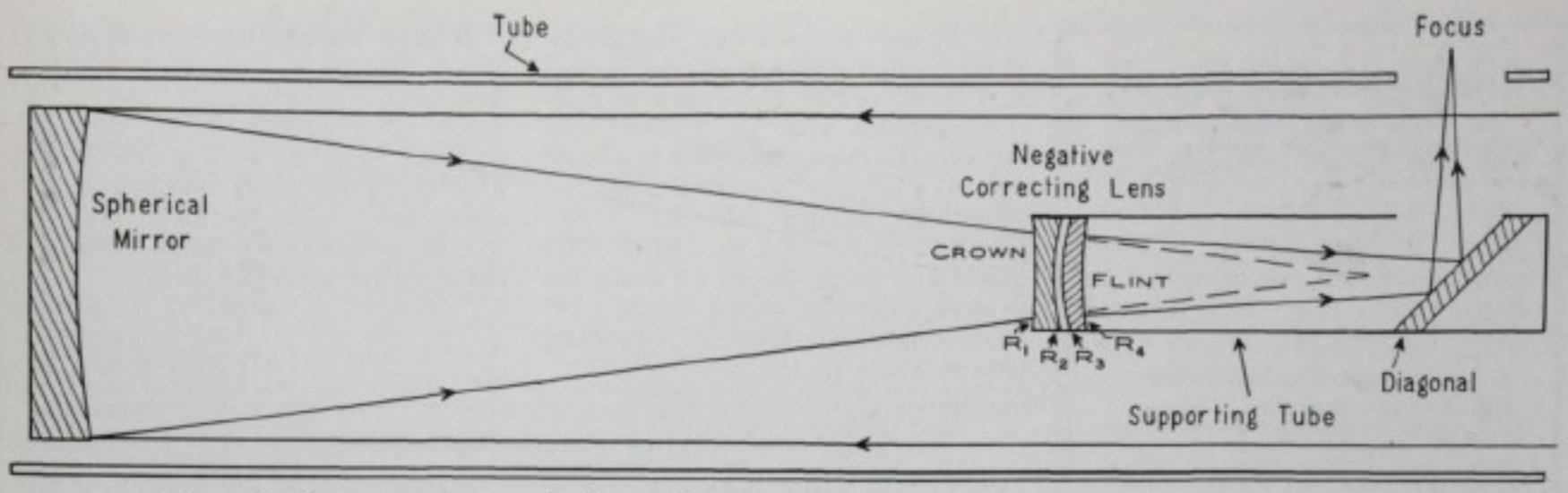
A well-known expedient for increasing the angular field of a Newtonian reflector is a neutral doublet correcting lens near the focus. Lenses of this type are used with the Mount Wilson and Palomar telescopes and other large reflectors. It has been pointed out by Baker and by C. G. Wynne, however, that such a doublet cannot correct spherical aberration, coma, and astigmatism simultaneously *if* the spherical aberration is already corrected at the primary.

Therefore, in the reflector-corrector designed by Baker, spherical aberration is introduced into the system by a figured plate, permitting subsequent complete correction by the lens. This arrangement has been used to adapt a conventional paraboloid to wide-angle photography (see *Sky and Telescope*, January, 1954, page 73), but it does not lend itself easily to amateur use.

In the design presented here, ordinary achromatism is achieved by the use of closely spaced elements of crown and flint glass, while the radii of the four surfaces have been adjusted to cancel the spherical aberration and coma of the primary mirror. The secondary spectrum (expressed as a fraction of the over-all focal length of the system) introduced by the power of the lens is less than half that of a comparable refractor, that is, an achromat having an aperture and focal length equal to the equivalent focal length of the new system.

The diagram shows the optical arrangement, which in my case incorporates a 6-inch spherical primary with a focal length of 24". The correcting lens is mounted in a tube that also contains the diagonal mirror. The first element (nearest the primary) is made of ordinary crown glass, 517645, while the second element is flint, 649338. (It should be

Only spherical optical surfaces are used in this compact reflector constructed by Robert T. Jones.



The optical system of Mr. Jones' telescope drawn to one-quarter of the scale of the actual instrument.

noted that this arrangement is the reverse of that in the conventional Barlow lens.)

Radii of the four surfaces have been computed for positions of the lens 5″ and 6″ inside the focus of the primary and for a fixed amplifying ratio of 1.92 to 1:

Inches inside focus	*Radii of curvature in inches*			
	R_1	R_2	R_3	R_4
5	−8.33	3.74	2.98	5.73
6	−12.69	4.11	3.54	6.76

Although the radii in the table were worked out for a primary focal length of 24″ (equivalent focal length 46″), they may be adapted to larger or smaller instruments by a proportionate scaling factor. For the particular amplifying ratio chosen, the (Gaussian) rays emerging from the crown lens into the space between the elements are parallel to the optical axis, so the correction is not extremely sensitive to the spacing of the components.

The calculations were made first by thin-lens theory and then verified in several instances by Seidel sums for the individual surfaces, allowing a thickness of 0.33″ for each element. The reader interested in the methods employed in such calculations should consult the article by C. G. Wynne in the *Proceedings* of the Physical Society (London), *62*, 360B, December, 1949.

In my first experiments with this design, a 1.4″ lens was placed only 4″ inside the focus (20″ ahead of the primary). The lens was made from standard blanks, using a small lathe and a miniature Draper-type polishing machine. Careful fine grinding and polishing resulted in spherical curves that required hardly any corrective figuring. The f/4 spherical primary is, I believe, easier to make than the conventional f/8 paraboloid.

The necessity of precise collimation in any compact optical system was forcibly demonstrated by the first observations with the newly assembled instrument. In my later experiments, the optical axis of the mirror has been permanently set by an aluminum ring machined so as to make a narrow contact with the optical surface just inside the mirror's edge. This ring, together with the spider supporting the secondary-lens tube, was then assembled permanently in the main tube with the aid of a machined jig.

The latter consists essentially of a steel tube threaded at one end to screw into the lens cell, and having a disk at the other end to hold the mirror ring in position. The ring and the spider are bolted in the main tube while still attached to the jig. Since the jig is made to run true on the lathe, it insures alignment.

This first telescope, however, was not definitely superior to a well-corrected Newtonian of the same equivalent focal length, since the angular field was not noticeably wider and some color and defocusing were apparent at the edges of the field.

When a larger corrector, 2″ in diameter, was installed 6″ inside the primary focus, these defects were removed—the field curvature was reduced and the correction of the remaining aberrations was extended over a wider field. It was found that a 1.6″ aperture stop in front of the 2-inch lens caused no obvious loss of performance, so that the corrector could probably be made that size advantageously, for there would be less diffraction and loss of light.

Since completion of this second modification, further studies of the design have indicated that, for particular amplifying ratios, a cemented doublet would reduce coma over a wide field to values below Baker's limit. The cemented de-

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Here is a combination of a Barlow and a particular ocular which gives outstanding results. It consists of our new Barlow and our 16.3-mm. (½″ focal length) Erfle eyepiece. While the Barlow was not specifically designed to work with this eyepiece, it does so to an astonishing degree. All images are sharp and hard to the very edge of the field.

The Barlow gives magnification up to slightly over three times that of the ocular alone. It is achromatic, coated, and mounted to the U. S. standard size of 1.250 inches.

The modified Erfle eyepiece has a field of 75 degrees with excellent eye relief. The combination gives the equivalent focal length of slightly under 6 mm. Many users state it is far superior to any shorter focal length ocular of equivalent magnification.

The Barlow sells for $16.00 postpaid, and the Erfle for $14.75 postpaid. Both are guaranteed to perform as stated above or money refunded.

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28-mm.	$15.00	10.5-mm.	$16.25	4-mm.	$17.25
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4¼"	¾"	$ 6.00
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10"	1¾"	$33.65
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sign requires that the flint element be placed nearest the primary, so its surfaces are R_1 and R_2. Using the same types of optical glass as in the previous lens, and with the elements finished to a thickness of 0.33", the cemented design requires the following radii: R_1 −7.58", R_2 −3.32", R_3 −3.32", R_4 +10.50". This corrector is to be placed 6" inside the focus of a spherical mirror having a 24" focal length, and gives an amplifying ratio of 2.5 to 1.

As many readers know, results similar to mine may be achieved, theoretically at least, with a Cassegrainian type of reflector. The present design, however, with only spherical surfaces, permits this theoretical performance to be approached more closely in an instrument that can be easily made by the amateur. (Commercial rights are reserved by me.)

ROBERT T. JONES
840 Lincoln Ave.
Palo Alto, Calif.

How Little Abrasive?

AMATEUR mirror makers often need to know how little of a particular abrasive will satisfactorily grind a surface. Although it is true that some of the best cooks do the least measuring, nevertheless the inexperienced usually find definiteness quite helpful.

From previous experience I have determined the values in the following table showing the suggested *minimum* quantities of dry abrasive to be placed on the lower disk prior to the addition of water. The quantities refer to single grinding spells or *wets*. Each grinding stage consists of many wets, using an abrasive of one particular size.

Abrasive		*Minimum Quantity in Milliliters* 4¼"	6"	8"	10"	12½"	*Grain Size in Inches*
Carbo	#60	—	—	15.8	24.7	38.6	0.0117
Carbo	#80	2.9	5.7	10.2	15.9	24.8	0.0075
Carbo	#120	1.9	3.7	6.7	10.4	16.2	0.0049
Carbo	#220	1.1	2.2	3.9	6.1	9.6	0.0029
Carbo	#280	0.6	1.2	2.0	3.2	5.2	0.00156
Carbo	#400	0.3	0.6	1.1	1.7	2.7	0.00081
Alundum	#600	0.2	0.3	0.5	0.7	1.1	0.00033
Emery	#305	0.1	0.2	0.3	0.4	0.7	0.000197

There are many variables that affect the efficiency of a wet, including pressure, length of stroke, speed of stroke, rate of rotation of the work, and the amount of moisture used. Quantities less than those given will reduce efficiency, making extra working time necessary on each stage. Amounts three times those listed in the table should be considered excessive. Grinding action takes place due to the abrasives rolling between the glass surfaces, and heavy charges of grits cushion and slow down the cutting action. This, like too little grinding material, means more wets and lost time.

The amounts shown for the 6-inch mirror were determined by the formula:

$$V = 16.39 \times 0.0376\ D/d,$$

V being the desired volume in milliliters, **d** the grain size in inches of No. 400 grit, and **D** the size in inches of the abrasive grain under consideration. The 0.0376 cubic inch is equivalent to the ⅛ teaspoonful recommended by Allyn J. Thompson for No. 400 (*Making Your Own Telescope*, page 44). The formula can be reduced to $V = 761\ D$. For mirrors other than 6-inch, the amounts listed were determined by the ratio of the area of a 6-inch to other mirror sizes.

A glass test tube graduated in tenths of a milliliter is obtainable from a local druggist. Be sure that it is well washed out, dry and warm each time you change to a finer grade of grit, so there can be no contamination of one abrasive by another.

After the dry abrasive has been placed on the bottom disk, water is mixed with it, and the mixture is evenly distributed

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6-inch..... **$6.50** 10-inch..... **$11.25**
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with your finger. The proper amount of water is determined by making a few grinding strokes and observing the degree of translucence of the mixture. For all stages except the last, there should be a slight translucence discernible through the upper disk at the beginning of a wet. As the grinding progresses and the abrasive is broken down, the mixture becomes totally opaque. When it becomes "muddy" instead of "sandy," it is time to wash off the mixture. In using extremely fine powders, such as emery No. 305, there should be a decided translucence or semiopaqueness at the beginning of a wet. Too watery a mixture (with great translucence), or the protracted working of a broken-down abrasive, might result in sticking of the surfaces being ground, a dangerous event.

As for the number of wets for each grade of abrasive, a good guide is Thompson's recommendation of six to 10 wets for each stage of carbo after roughing out is completed, and about five wets for No. 305 emery. As is pretty well known, careful workers do not terminate rough grinding until the sphericity of the curve is good, and in fine grinding they do not go on to a finer abrasive until 60 minutes of actual stroking has taken place.

The table is based on using pyrex mirrors and pyrex tools while grinding, although a plate-glass tool should make little difference. Few amateurs grind plate-glass mirrors these days, but if such faster-cutting glass is used the suggested amounts still apply. It is better to grind extra and have no pits than to skimp or cut down on the grinding and end up with a mirror on which a complete polish cannot be obtained.

In the roughing-out stage, up to No. 120 carbo, the use of chordal strokes will require less material than the amounts listed in the table; the table is calculated for grinding sessions when center-over-center strokes are employed with an unchanneled tool.

If a channeled tool is used, the abrasive quantity will have to be greater, but the matter of translucence is the same as for an unchanneled tool. It is difficult to use too much abrasive with a channeled tool, for excess grits are immediately pushed into the channels. Such a tool also results in a better edge; at best the unchanneled tool produces a slightly turned-down edge as tested under the angle-of-incidence setup.

How much turned edge can we tolerate before going on to polishing? I found that if a light, single flick of the finger at the extreme edge zone would temporarily make the reflection from that zone brighter than the reflection from the center zone, then the mirror could go into polishing with assurance that the edge would come out right on a good hard lap. Many mirror makers depend on this simple test.

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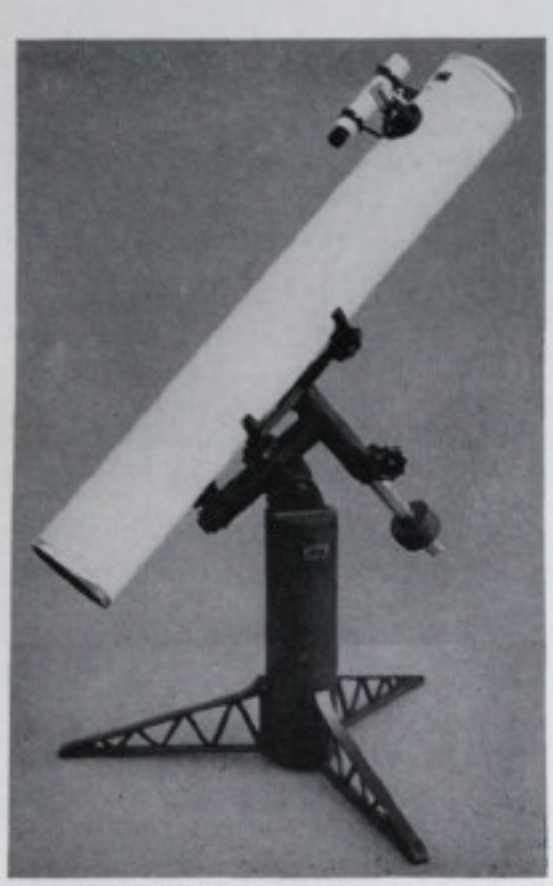

Standard Model "A" 6-inch ASTROLA, f/8, complete with 3 oculars (72x, 180x, 315x)
$295.00

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These instruments are fully portable—as they can be assembled or taken down in three minutes. Each comes with three of the finest oculars. The equatorial head and stand are of cast aluminum. The fiberglass tube is made by W. R. Parks. Optics are corrected to ⅛" wave or better and are quartz coated. ASTROLAS will resolve double stars to the Dawes limit. Clock drives, rotating tubes, setting circles furnished at additional cost.

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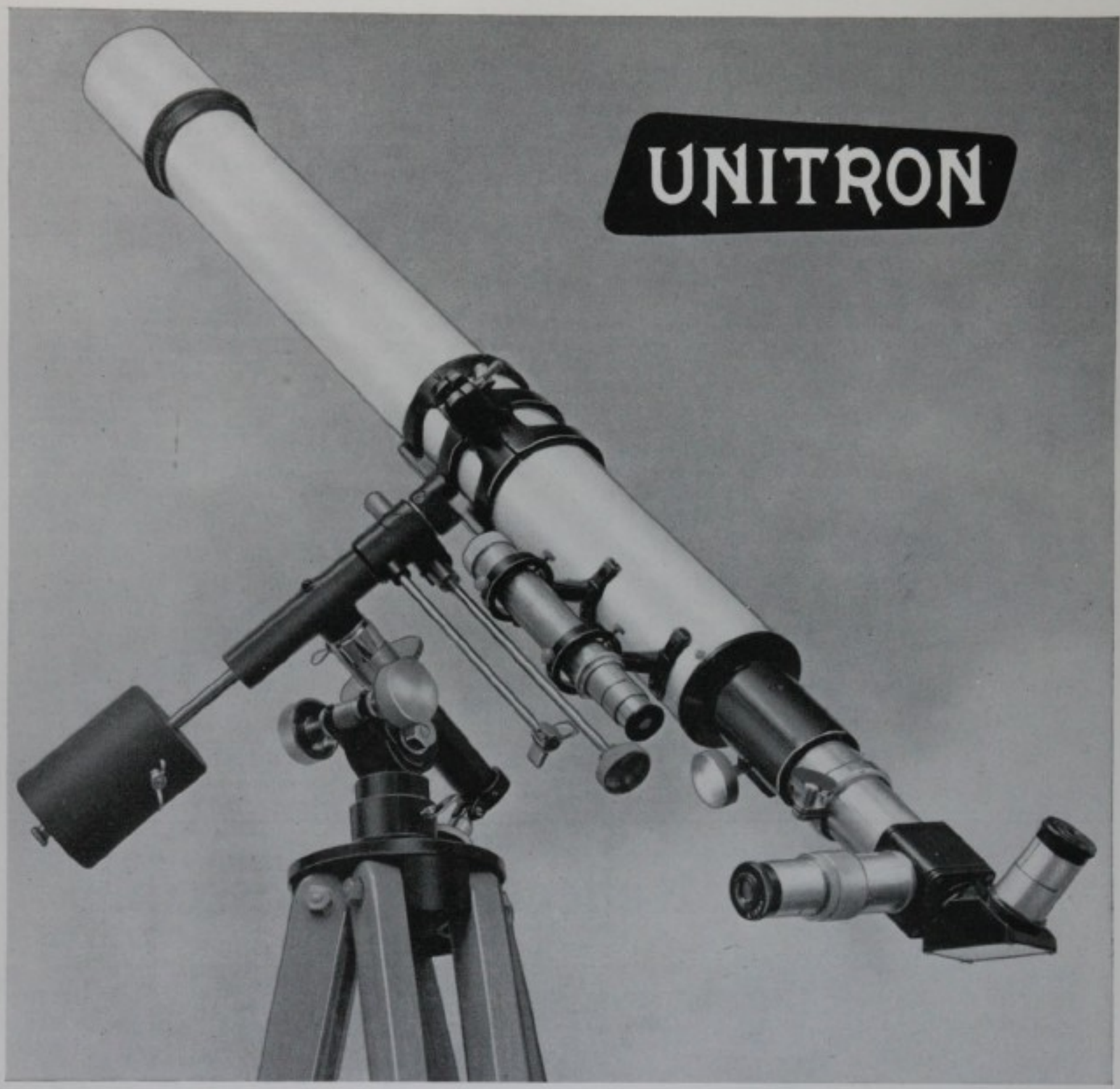
All prices F.O.B. our plant, Long Beach, Calif., and subject to change without notice. Send for catalogue.

CAVE OPTICAL COMPANY

4137 E. Anaheim St., Long Beach 4, Calif.



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Since it is a UNITRON, it can boast of an optical system of unexcelled performance, which produces images of startling clarity and definition. And like every UNITRON Equatorial, it is equipped with velvet-smooth, slow-motion controls for both right ascension and declination.

The UNITRON 2.4" Equatorial Refractor is priced at only **$225**, complete with 5 eyepieces, view finder, choice of UNIHEX Rotary Eyepiece Selector or star diagonal and erecting prism system, sunglass, and cabinets. Using our Easy Payment Plan, a down payment of only $22.50 is required and you have 12 months to pay the balance. The companion UNITRON 2.4" Altazimuth model is only **$125** complete, and requires only $12.50 down.

Extra accessories offered include the DUETRON Double Eyepiece (illustrated in the photo above), Astro-Camera 220, and the sun projecting screen. Four extra eyepieces are available to bring to nine the number of magnifications possible with this instrument.

The UNITRON 2.4" models are but two of the many famous UNITRONS that you have heard so much about. Don't miss out on the fine observing — treat yourself to a UNITRON.

See the back cover.

UNITRON INSTRUMENT DIVISION of UNITED SCIENTIFIC CO.
204-206 MILK STREET BOSTON 9, MASSACHUSETTS

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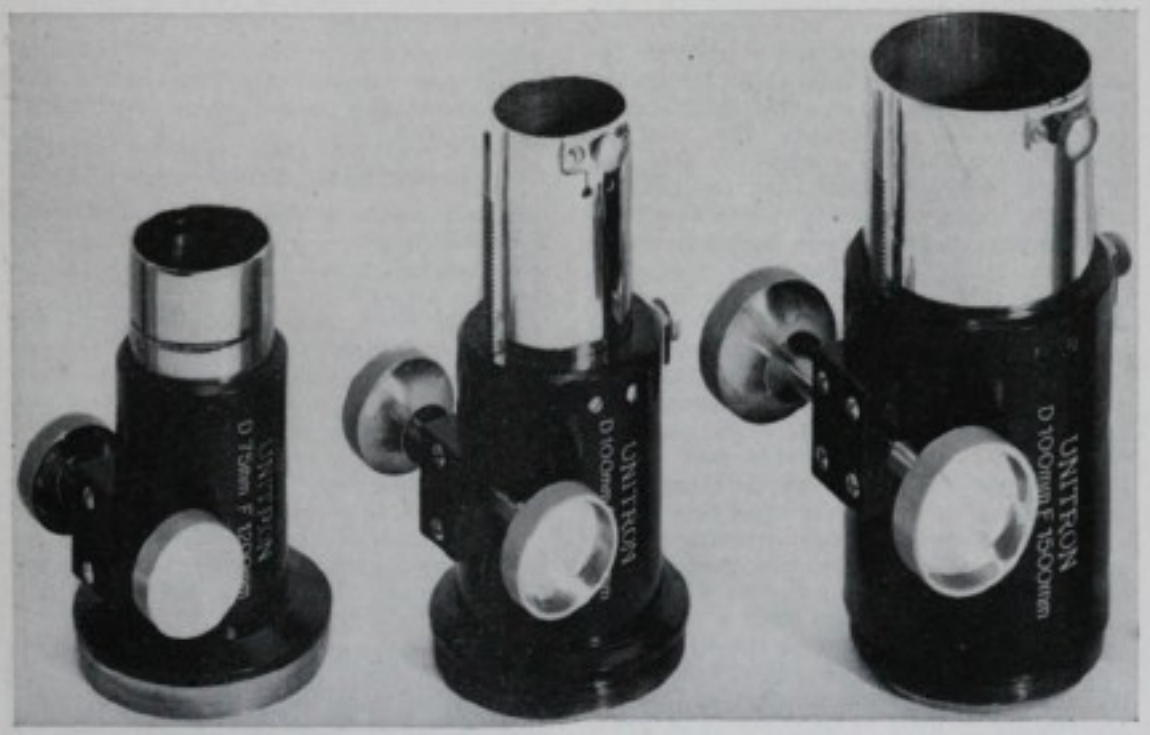
UNITRON Telescope Accessories and Components are all standard equipment in UNITRON Refractors and are therefore of the finest quality obtainable. Items available include objective lenses, eyepieces, view finders, sun projecting screens, star diagonals, and the famous UNIHEX and DUETRON. All are illustrated, described, and priced in the UNITRON Catalog.



RACK-AND-PINION FOCUSING MECHANISMS: Shown above, left to right, **Standard, De Luxe,** and **Super** Models. Prices include long drawtubes with eyepiece holders for both 24.5-mm. and 1¼" O.D. eyepieces. The Super model can, in addition, hold our giant 60-mm. f.l., 58-mm. O.D. eyepiece. The Super and De Luxe Models have locks for both the drawtube and focusing sleeve. Shipped postpaid.

Standard Model	**Only $12.50**
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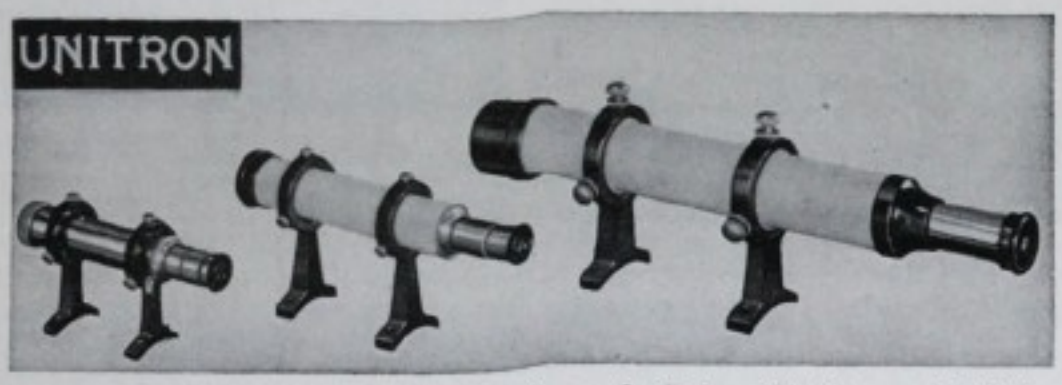

L. to R.: (1) 23.5-mm. 6x finder; (2) 30-mm. 8x finder; (3) 42-mm. 10x finder

1. VIEW FINDER (As used on UNITRON 2.4" Equatorial): 23.5-mm. (.93") achromatic objective, 6x eyepiece with crosshairs. Chromed brass tube. Mounting brackets with centering screws.

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4" PHOTO-EQUATORIAL with clock drive and astro-camera (**$117.50 Down**), with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x	**$1175**
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Higher- and lower-power eyepieces available for all models. Prices include basic accessories, tripod and mounting, fitted wooden cabinets, and operating instructions. Additional accessories available to add further to your observing pleasure. All UNITRON instruments are fully guaranteed for quality, workmanship, and performance, and must meet with your approval, or your money back.

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- How to choose a telescope
- Amateur clubs and research programs

UNITRON *Instrument Division* of UNITED SCIENTIFIC CO.
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Please rush to me, free of charge, UNITRON'S new Observer's Guide and Telescope Catalog.

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ON THE PROBLEM OF CHOOSING A TELESCOPE

The choosing of a personal telescope nowadays must be very difficult for any newcomer to the field of astronomy. Thirty years ago when we ourselves became amateurs there was not any "Sky and Telescope" magazine to bedazzle our eyes every month with its host of instrumental offerings for every purse and purpose. Back in those practically prehistoric times you could arrange to have a refractor custom-built at home or abroad, or you could make yourself a reflector if you had heard of the wonderful new book just published by the now legendary A. G. Ingalls, called "Amateur Telescope Making." Since there were almost no war-surplus items, a great many of us got our first glimpses of the sky through some battered spyglass from a dusty pawnshop.

Today your choice is wide indeed, but choosing is not easy. Should it be a reflector or refractor? Should you buy a lot of aperture and skimp on mounting, or vice versa? Should you make part of it yourself? Should it be portable, semiportable, or a permanent job with some sort of shelter? How big ought the doggone thing to be? What power should it have, and how many eyepieces? Above all, since everybody says his telescope is wonderful, whom can you believe, and what size and make are really the best?

We'd like to talk about size of aperture this month. As you know, the larger the aperture, the smaller the diffraction image, and the greater the resolving power. Theory says so, and controlled laboratory tests confirm it for all optical systems of requisite quality. Thus one may test a large lens or mirror in the laboratory and secure wonderful resolution, only to mount it and have it prove most disappointing on the sky itself if seeing conditions are not right. Until quite recently, little thought had been given to improving the inherent defects of the conventional 18th century refracting and reflecting telescopes.

It took 50 years for the simple reflector of Newton, and the compound ones of Cassegrain and Gregory, to come into use, and about a century to perfect the so-called achromatic lens. At the turn of the 20th century, the catadioptric or mixed-lens-and-mirror systems of Goerz and Schupmann wholly escaped the notice of astronomers, while as late as 1930 Bernhard Schmidt's invaluable telescope was invented but went begging for many years. Then in 1944 Maksutov's classic paper on the all-spherical catadioptric systems appeared in the "Journal" of the Optical Society of America, but created no noticeable astronomical furor.

In 1946, feeling that something important to astronomers everywhere should not be overlooked, the Questar project was embarked upon. Eight years and a quarter-million dollars later the first Questar telescope was sold from our announcement in the June, 1954, issue of "Sky and Telescope." At one stroke the wonderful new catadioptric optics were introduced in an 89-mm. photovisual form, and for the first time a compound telescope was in regular production, with the only f/2 Cassegrain design of which we know.

Without going into the myriad improvements and elegances of this delightfully compact new instrument, we were much impressed by the better-than-theoretical performance of our little artifact. As public acceptance grew, others also discovered that nature indeed seems to favor the superfine small aperture. The series of lunar photographs taken with their Questar by the Davises of Florida, who last December were absolute novices at this sort of thing, not only astounded us, but, we are told, quite astonished the astrophotographic experts at Eastman Kodak Research Laboratories.

As the returns gradually reach us from Questar owners everywhere, in far places and from several continents, it seems that their experience with the superfine Questar's 3½-inch aperture is often similar. The new Questar optics in their short, closed 8-inch tube seem able to pierce poor seeing like a keen rapier, giving a respectable image in seeing so poor as to cripple larger apertures severely, and in fine seeing are reported as nearly equaling the performance of perfect 6-inch refractors and 8-inch reflectors. This sounds like such a whopping claim that we are glad only to be passing on what people tell us. To what extent the unrivaled observing comfort of Questar contributes is hard to say, but it is probably considerable.

A typical experience is that of Mr. M, who is executive vice-president of a large corporation, and who purchased his first Questar in July, 1954. We thought you'd like to read two letters from him in our files, which we publish with his permission.

"I expect you will remember me as one of the earlier purchasers of Questar. . . . I was a novice at astronomy at that time although experienced with many types of optical instruments.

"About a year ago I got all fired up with enthusiasm and ambition and decided that my Questar was not sufficient for my needs—I had to have something bigger and better. Consequently, I purchased a 4-inch refractor (which didn't do a thing that Questar couldn't do better and besides was a major project to set up and use), disposed of this, and now own a very good 8-inch reflector.

"My Questar had been admired by Dr. X, professor of astronomy at the college here, so in a rash moment I presented it to the school. I do not regret this because it is now being used in the best possible manner, but I miss it. After having experience with the larger instruments I now fully appreciate the importance of Questar's ease of operation. I also know that although in theory these larger scopes should outperform Questar, in practice they don't always do it. In fact, I am wondering if the larger instruments are really worth it to the average amateur. In September I had a chance to view Mars through a large observatory telescope and at the same time compare it with a 5-inch refractor. To me there was not a nickel's worth of difference, and Dr. X himself spent most of his time at the 5-inch. Of course, I realize there is no substitute for aperture when it comes to viewing and photographing the far-distant and faint objects, but as I see it, there is not much useful or interesting work that an amateur can do in that field anyway."

(This letter ended with shipping instructions for another Questar, receipt of which Mr. M acknowledged Nov. 26, 1956, saying, "The weather here is poor now . . . I have learned never to judge performance on one night's viewing.")

Later, on June 15, 1957, we received the following letter from him:

"Just a note to tell you what excellent results I obtained in observing last night. Although the moon was full, it was one of the best nights for seeing in my experience.

"At 160 power, Cassini's division in the ring of Saturn was plainly visible, as was the apparent shadow of the rings on the surface of the planet itself. Two of Jupiter's bands were quite prominent, with an occasional suggestion of a third. When I switched to my 8-inch reflector, I found that very little more detail on either of the planets could be observed.

"At approximately midnight, when Lyra was approaching the zenith, I obtained the most perfect split of the Epsilon Lyrae pairs that I have ever observed with any instrument. Although this separation of about 2 seconds is well over Questar's theoretical limit of approximately 1.3 seconds, I was most gratified, since in my experience it is most difficult ever to utilize an instrument's theoretical limit."

This is another moon picture by a Questar owner, showing the south central portion of the moon's disk, in the region of Mare Nubium. The prominent crater near top center is Tycho, with its central mountain.

The list of Questar owners is now a most impressive one. Many government agencies beside the armed services are represented, as are industrial users such as Corning Glass and Sperry Gyroscope. Men and women in all walks of life are Questar owners, and many of them are quite distinguished persons. Some teachers of astronomy at schools, colleges, and universities are finding Questar so rewarding in a number of ways that their large instruments are only used when unusually fine seeing justifies the inconvenience.

If you, too, have become tired of coping with the burden of large single-purpose telescopes, perhaps you would like to learn more about the incomparable Questar. Literature and details of our time payment plan are yours upon request.

The DeLuxe Questar at $995 and the Field Model at $495 are identical but for their mountings.

QUESTAR CORPORATION
New Hope, Pennsylvania

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Northern Lights Usher in the IGY

A BRILLIANT auroral display was widely observed in many parts of the United States on the night of June 30-July 1, the official starting date for the International Geophysical Year. There were also auroras preceding this one and for several days thereafter, coinciding with a high level of solar activity.

At Havertown, Pennsylvania, Michael J. Morrow noted a large number of sunspots on June 30th, and that evening saw a rayed auroral band about 10 degrees above the northern horizon. Within the next hour, by 10:20 p.m. Eastern standard time, the band brightened considerably and began to pulsate. Long rays then appeared, extending upward past the Big Dipper and near Polaris. By 45 minutes after midnight, the aurora was once again a pulsating band of light in the north.

A photographic record was kept by Walter A. Feibelman at Pittsburgh, Pennsylvania, who first began observing at about 10:15 p.m., when a faint greenish double arc was visible at the horizon. Shortly afterward a corona formed near the zenith and some rays were located as far south as Scorpius. Flaming aurora was seen, the flashes taking about half a second to travel from near the horizon to the zenith. The display lasted until about midnight, and on the following three evenings Mr. Feibelman noticed no traces of aurora before midnight.

A faint reddish streamer, high in the northwestern sky, first attracted the attention of Cletus Kurtzman, of Mansfield, Ohio, at 10:40 p.m. EST, but it faded away in a few minutes and the northern sky became covered by a mass of whitish moving lights. Again flaming aurora was seen and the "rippling" persisted during the entire subsequent display. A coronal aurora formed briefly in Hercules.

Roger J. Cuffey, Bloomington, Indiana, first noticed the aurora as a "faint, flickering, greenish glow" at 9:45 p.m. Central standard time. In the next 10 minutes rayed bands developed, extending between 30 and 50 degrees above the horizon and from azimuth 340° to 65°. The streamers west of the meridian were all reddish, while those to the east were greenish. By 10:35 the auroral activity had ended.

At Plover, Wisconsin, two homogeneous arcs, about six degrees apart and each about half a degree wide, extended from due west to northeast early in the evening, and soon became the source of many rays. Richard A. Phelps reports that at 9:30 CST, the sky was "full" of aurora with a large, very red spot in the northwest and with steady, nonpulsating rays reaching from the low north to the zenith. These rays were so bright as to make it difficult to see any stars in Cassiopeia. Mr. Phelps, who had planned to take photographs, abandoned this project to make notes at five-minute intervals until 11:10 p.m., "since there was such an enormous amount of activity."

Rex Powell, Lawrence, Kansas, concluded that the peak of the display occurred at about 9:45 p.m. CST, with red-orange rays extending through Polaris to a height of 55 degrees. At 10:07 he observed two arcs, the lower and more distant one being only three degrees above the horizon, yet extending nearly 30 degrees east and west of north.

Stephen Sinotte, Keokuk, Iowa, estimated that the northern lights covered about half of the sky at 10 o'clock in the evening. Homogeneous arcs and bands predominated, but rayed forms were quite strong, and the pulsations were fairly rapid. An hour later the activity had died down, but homogeneous bands were still visible.

A call from an amateur radio operator who was having short-wave reception troubles prompted Dr. J. R. Otoupalik to look outdoors for possible northern lights at Greeley, Colorado. He found a green-white glow 30 degrees high extending 90 degrees along the northern horizon.

Apparently the June 30th display continued more-or-less active all night. Amateurs in the suburbs of Boston, Massachusetts, spent the early morning hours of July 1st watching a complete sequence of auroral forms, including strong flaming aurora and a large corona. The height of this activity was reached about 2:00 a.m. EST.

David E. Grebe, Kaukauna, Wisconsin, took the accompanying photograph of an aurora he witnessed on June 28-29. Dr. Otoupalik reports that the display he observed July 4-5 was better than that of June 30th; he noted strong flashes of light, with Cassiopeia as a backdrop in the northeast. Mr. Sinotte believes that a greenish glow he saw on July 5-6 was of an auroral nature, although it was difficult to distinguish it from moonglow since there was much haze toward the northern horizon.

Although San Jose, California, is located far from the zone of greatest auroral frequency, three displays were seen there and are reported by Stephen W. Bieda, Jr. On the night of the annual star party of the B and C Observatory, June 28-29, a pronounced glow was seen in the north at 10 p.m. PST; it lasted for an hour and a half and was ob-

Left: At about one o'clock in the morning of June 29th, two nights preceding a more widely observed display, this group of auroral rays was photographed in the southeastern sky by David E. Grebe, Kaukauna, Wisconsin.

Right: The aurora was very bright at 10:30 p.m. June 30th, when Walter A. Feibelman made this picture at Pittsburgh.

served also by Charles Gardiner, Robert Cunningham, and James Styczynski. Three nights later, the last of these observers watched a faint glow and some rays from 8:40 to 9:10 p.m., and Mr. Bieda recorded a very faint auroral glow during the hour ending at 11 p.m. Finally, on July 2-3, the San Jose amateurs saw a more active display, the maximum intensity of which was probably lessened by twilight glow.

DEEP-SKY WONDERS

VULPECULA, a constellation of faint stars lying at the foot of the Northern Cross, reaches a favorable observing position in northern autumn skies. It abounds in open star clusters, which are plotted in Norton's and the Skalnate Pleso atlases, but it is, perhaps, best known for a great planetary nebula.

This is NGC 6853, M27, the famous Dumbbell nebula, located at 19ʰ 57ᵐ.5, +22° 35′ (1950 co-ordinates). It is about magnitude 7.5, and some 8′ by 4′ in extent. A binocular will show it, but no instrument ever exhausts the additional detail that may be seen as larger telescopes are turned to it.

Messier 27, photographed by S. R. B. Cooke, Minneapolis, Minnesota.

The peculiar shape of this planetary is shown by Strathmore R. B. Cooke's Schmidt camera photograph, but may be vague in the average 3-inch refractor or 6-inch reflector. In a 10-inch the Dumbbell is a marvelous spectacle, while in the 40-inch reflector of the Flagstaff station of the U. S. Naval Observatory, it is seen to be like the photograph on page 8 of the November, 1956, issue.

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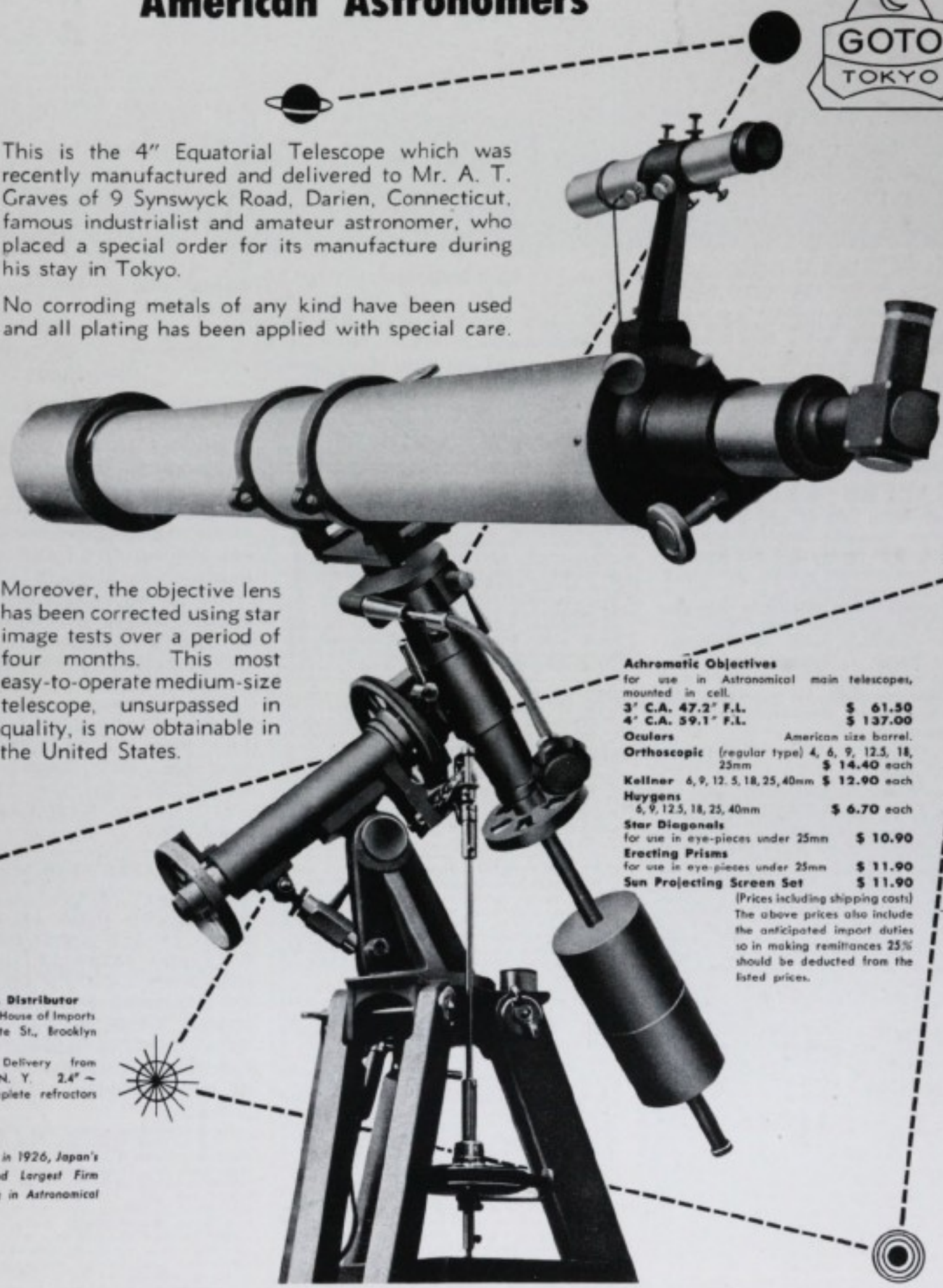

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OCCULTATION PREDICTIONS

August 31-September 1 **Psi Ophiuchi** 4.6, 16:21.6 −19-56.3, 7. Im: **C** 2:31.6 −0.2 +1.2 30; **F** 2:02.2 . . . . . 37.

August 31-September 1 **Saturn** 0.7, 16:26.1 −20-04.7, 7. Im: **E** 4:23.5 −0.3 −0.5 61; **F** 4:24.9 −0.8 −0.7 78; **H** 4:01.5 −1.4 +0.8 43. Em: **H** 4:56.2 −1.9 −2.7 316. See page 504 of the August issue for further details on the occultation of Saturn.

September 27-28 **Beta Scorpii** 2.9, 16:02.9 −19-41.4, 4. Im: **H** 2:10.3 −1.8 −1.8 121. Em: **H** 3:15.7 −0.8 −0.3 243.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude **(Lo − LoS)**, and multiply **b** by the difference in latitude **(L − LS)**, with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
	I	+123°.1,	+49°.5		

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Hygiea, 10, 9.9. September 9, 0:59.6 +12-02; 19, 0:53.7 +11-34; 29, 0:46.6 +10-56. October 9, 0:39.2 +10-10; 19, 0:32.2 +9-22; 29, 0:26.1 +8-35.

Bruchsalia, 455, 9.7. September 19, 1:32.7 −15-13; 29, 1:25.7 −15-41. October 9, 1:16.8 −15-42; 19, 1:07.7 −15-11; 29, 1:00.0 −14-04. November 8, 0:55.0 −12-28.

Vesta, 4, 6.8. September 19, 1:24.7 −3-41; 29, 1:16.6 −4-48. October 9, 1:07.3 −5-48; 19, 0:58.0 −6-33; 29, 0:49.9 −6-58. November 8, 0:43.7 −7-01.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

SUNSPOT NUMBERS

June 1, 144, 158; **2,** 168, 163; **3,** 173, 180; **4,** 168, 169; **5,** 175, 159; **6,** 167, 194; **7,** 134, 170; **8,** 146, 145; **9,** 153, 168; **10,** 140, 158; **11,** 144, 140; **12,** 165, 160; **13,** 175, 179; **14,** 155, 159; **15,** 200, 239; **16,** 198, 248; **17,** 221, 252; **18,** 265, 274; **19,** 229, 280; **20,** 233, 285; **21,** 221, 275; **22,** 222, 260; **23,** 212, 250; **24,** 208, 235; **25,** 192, 210; **26,** 169, 230; **27,** 158, 238; **28,** 150, 190; **29,** 172, 186; **30,** 192, 213. Means for June: 181.6 American, 205.6 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by Dr. Sarah J. Hill from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

Predictions of the smoothed monthly sunspot numbers have been supplied by Dr. M. Waldmeier for the coming months: October, 157; November, 153; and December, 150.

NEW ZEALAND SUNSPOT NUMBERS

The Carter Observatory, Wellington, New Zealand, has recently issued *Solar Observations—Report No. 1,* summarizing systematic sunspot observations in New Zealand during the first quarter of 1957. The same publication also lists monthly mean sunspot numbers for 1955 and 1956 from New Zealand observations alone:

1955 January, 26.8; February, 24.0; March, 5.9; April, 10.2; May, 26.8; June, 25.7; July, 29.6; August, 39.3; September, 44.9; October, 57.4; November, 93.1; December, 83.5.

1956 January, 76.6; February, 114.5; March, 117.3; April, 100.2; May, 111.2; June, 103.9; July, 117.7; August, 177.8; September, 168.3; October, 160.9; November, 186.3; December, 170.3.

1957 January, 161.9; February, 124.3; March, 150.9.

VARIABLE STAR MAXIMA

September 1, R Corvi, 121418, 7.6; 3, T Cassiopeiae, 001755, 7.8; 4, R Lyncis, 065355, 7.9; 6, T Hydrae, 085008, 7.7; 7, R Centauri, 140959, 5.9; 10, RR Sagittarii, 194929, 6.6; 12, T Aquarii, 204405, 7.9; 13, R Leonis, 094211, 5.9; 17, Z Ursae Majoris, 115158, 6.6; 27, R Carinae, 092962, 4.6; 30, R Ophiuchi, 170215, 7.6.

October 4, R Sculptoris, 012233, 5.8; 6, RU Sagittarii, 195142, 7.2; 10, T Cephei, 210868, 5.8.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

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SAVE from 15% to 30% on complete Hi-Fi package unit, or empty speaker and equipment cabinets direct from North Carolina furniture factory. Write Daily Manufacturing Co., Dept. S, Box 888, Salisbury, N. C.

WANTED: Questar. State price and condition. J. C. Turner, P. O. Box 1126, Freeport, Tex.

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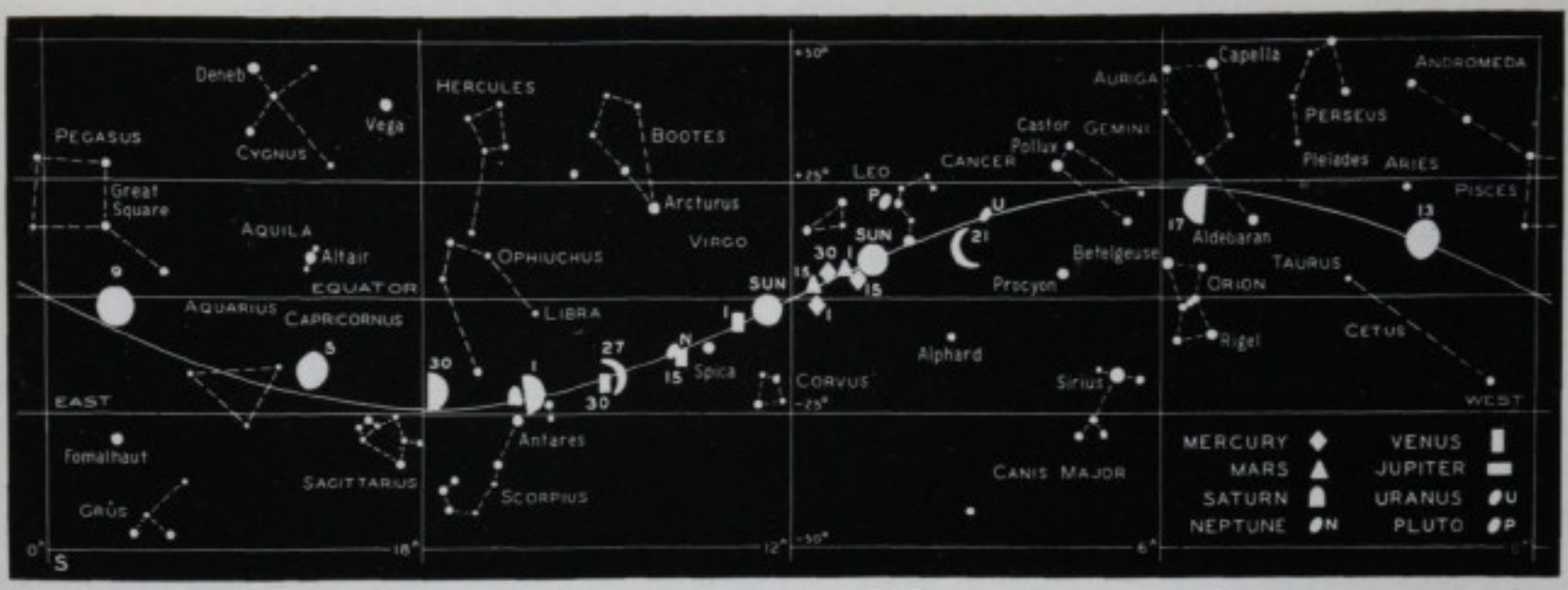

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury enters the morning sky on September 9th, passing rapidly from inferior conjunction to reach greatest elongation on the 25th, when it will be 17° 52′ west of the sun. This is the most favorable morning elongation of the year, and for two weeks beginning on September 20th Mercury can be seen with little difficulty. Ruddy in color compared with the nearby stars in Leo, the planet will rise just as dawn begins, somewhat to the north of the east point of the horizon. In little more than two weeks, Mercury's brightness will increase more than six times, from magnitude +1.2 on September 18th to −0.8 on October 3rd.

Venus continues bright in the evening sky, setting 1½ hours after the sun. Look for it in the southwestern heavens immediately after sunset. Its magnitude is −3.5 on the 15th, when its telescopic disk will be only 14″.8 in diameter and 75-percent illuminated.

Earth arrives at heliocentric longitude 0° on September 23rd at 7:27 Universal time, with autumn commencing in the Northern Hemisphere and spring in the Southern.

Mars cannot be seen, as it arrives at conjunction with the sun on September 21st.

Jupiter disappears into the sunset glow early in the month.

Saturn sets about 3½ hours after the sun in midmonth. It is visible as an object of magnitude +0.7 in the southwestern sky in the early evening. Saturn is in Ophiuchus, about 6° north of Antares and moving slowly eastward. The ring system presents its northern face, with an inclination of 26° to our view on the 15th.

On the evening of August 31-September 1 there will be a close conjunction of Saturn and the moon, with Saturn 34′ south as seen from the center of the earth at 3:33 UT. The planet will be occulted for observers in the central and western United States; details were given on page 504 of the August issue.

Uranus emerges from the sun's vicinity at the end of the month, and is located about 2½° east of Delta Cancri.

Neptune is too close to the sun to be observed.

E. O.

MOON PHASES AND DISTANCE

First quarter	September 1,	4:34
Full moon	September 9,	4:55
Last quarter	September 17,	4:02
New moon	September 23,	19:18
First quarter	September 30,	17:49
Full moon	October 8,	21:42

	Distance	Diameter
September		
Apogee 8, 17^h	252,500 mi.	29′ 24″
Perigee 23, 5^h	222,300 mi.	33′ 24″
October		
Apogee 5, 22^h	252,300 mi.	29′ 26″

MINIMA OF ALGOL

September 3, 5:02; 6, 1:51; 8, 22:40; 11, 19:28; 14, 16:17; 17, 13:06; 20, 9:54; 23, 6:43; 26, 3:31; 29, 0:20. October 1, 21:08; 4, 17:57.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

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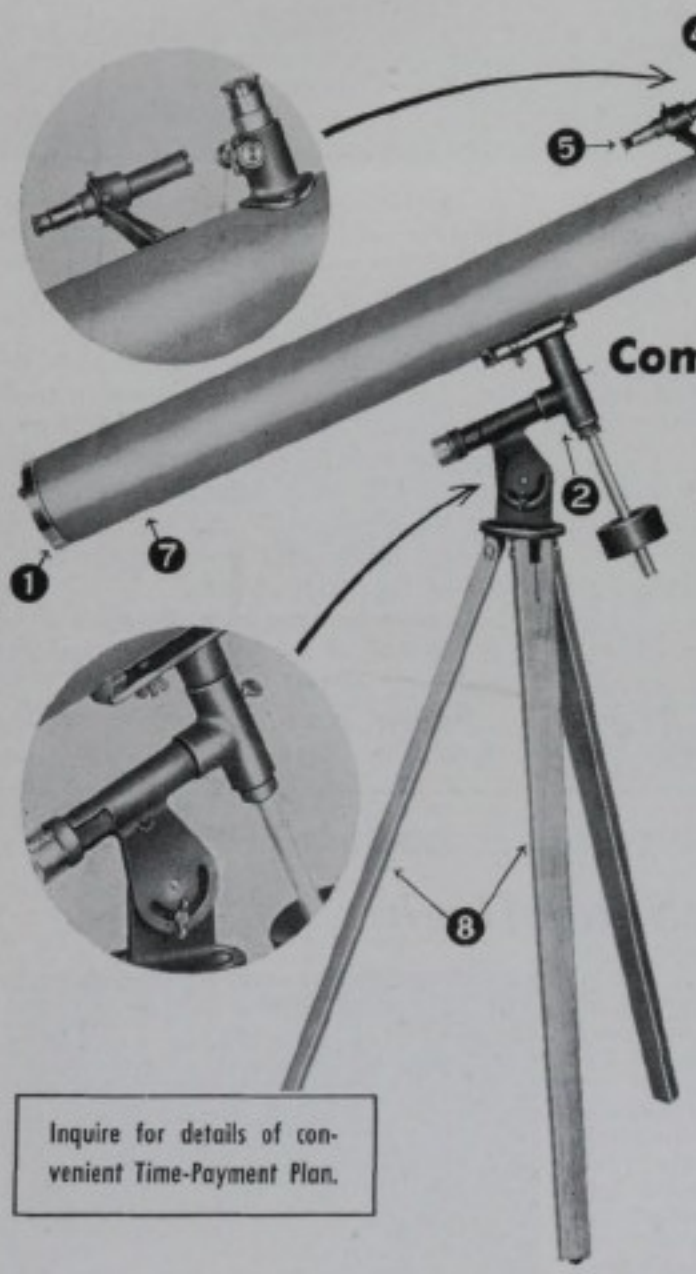

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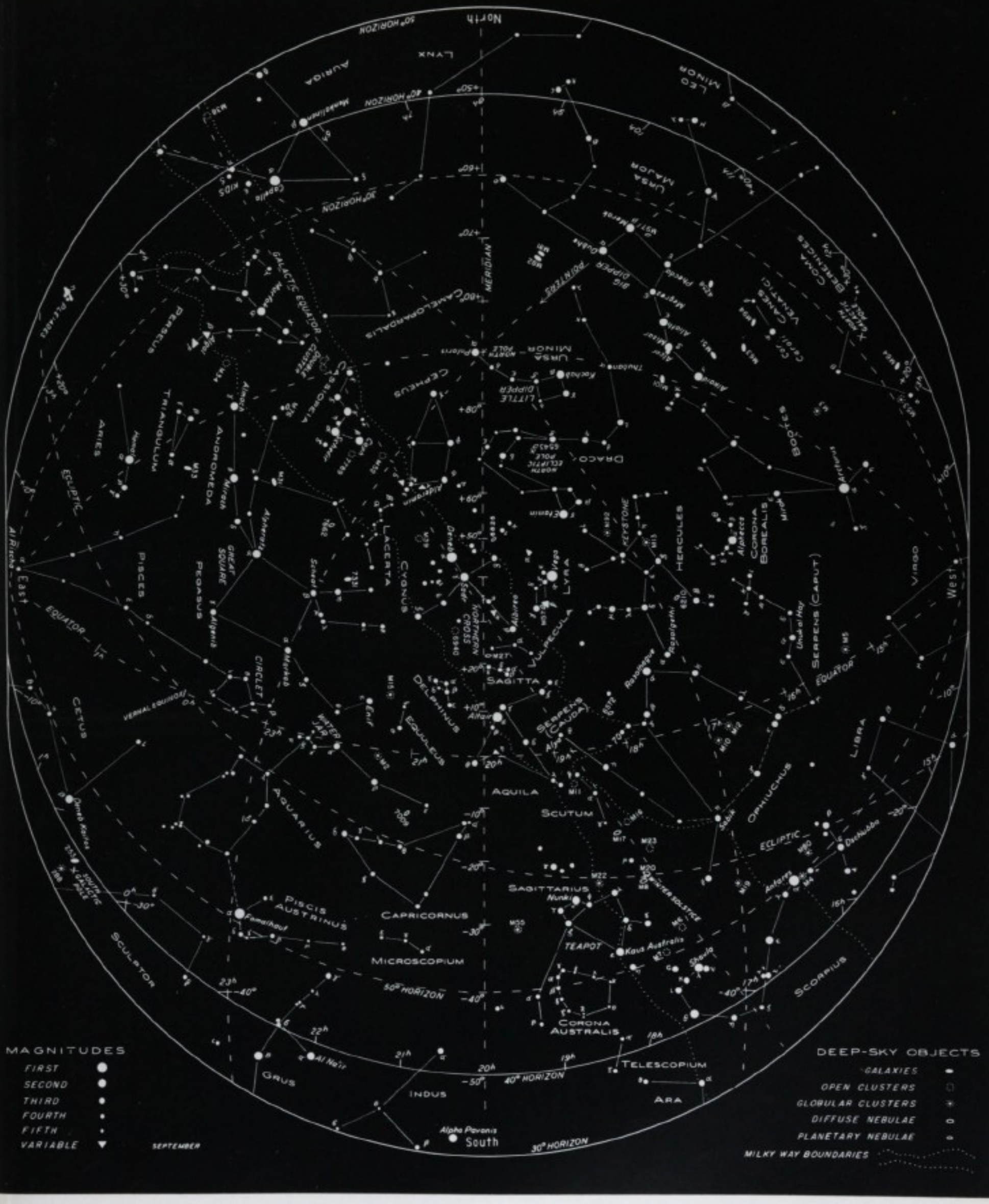

STARS FOR SEPTEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of September, respectively; also at 7 p.m. and 6 p.m. on October 7th and 23rd. For other dates, add or subtract ½ hour per week.

Cepheus, one of the least known of the circumpolar constellations, attains a favorable observing position this month. Its stars form a triangle set against a square, with one corner of the latter marked by three stars, including the famous variable, Delta Cephei.

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54 mm (2⅛")	390 mm (15.4") ...	9.75	83 mm (3¼")	876 mm (34½") ...	28.00
54 mm (2⅛")	508 mm (20")	12.50	83 mm (3¼")	1016 mm (40")	30.00
54 mm (2⅛")	600 mm (23½") ...	12.50	102 mm (4")	876 mm (34½") ...	60.00
54 mm (2⅛")	762 mm (30")	12.50	108 mm (4¼")	914 mm (36")	60.00
54 mm (2⅛")	1016 mm (40")	12.50	110 mm (4⅜")*	1069 mm (42⅛") ..	60.00
54 mm (2⅛")	1270 mm (50")	12.50	110 mm (4⅜")	1069 mm (42⅛") ..	67.00
78 mm (3⅛")	381 mm (15")	21.00	128 mm (5⅛")*	628 mm (24¼") ...	75.00
80 mm (3⅛")	495 mm (19½") ...	28.00	128 mm (5⅛")	628 mm (24¼") ...	85.00
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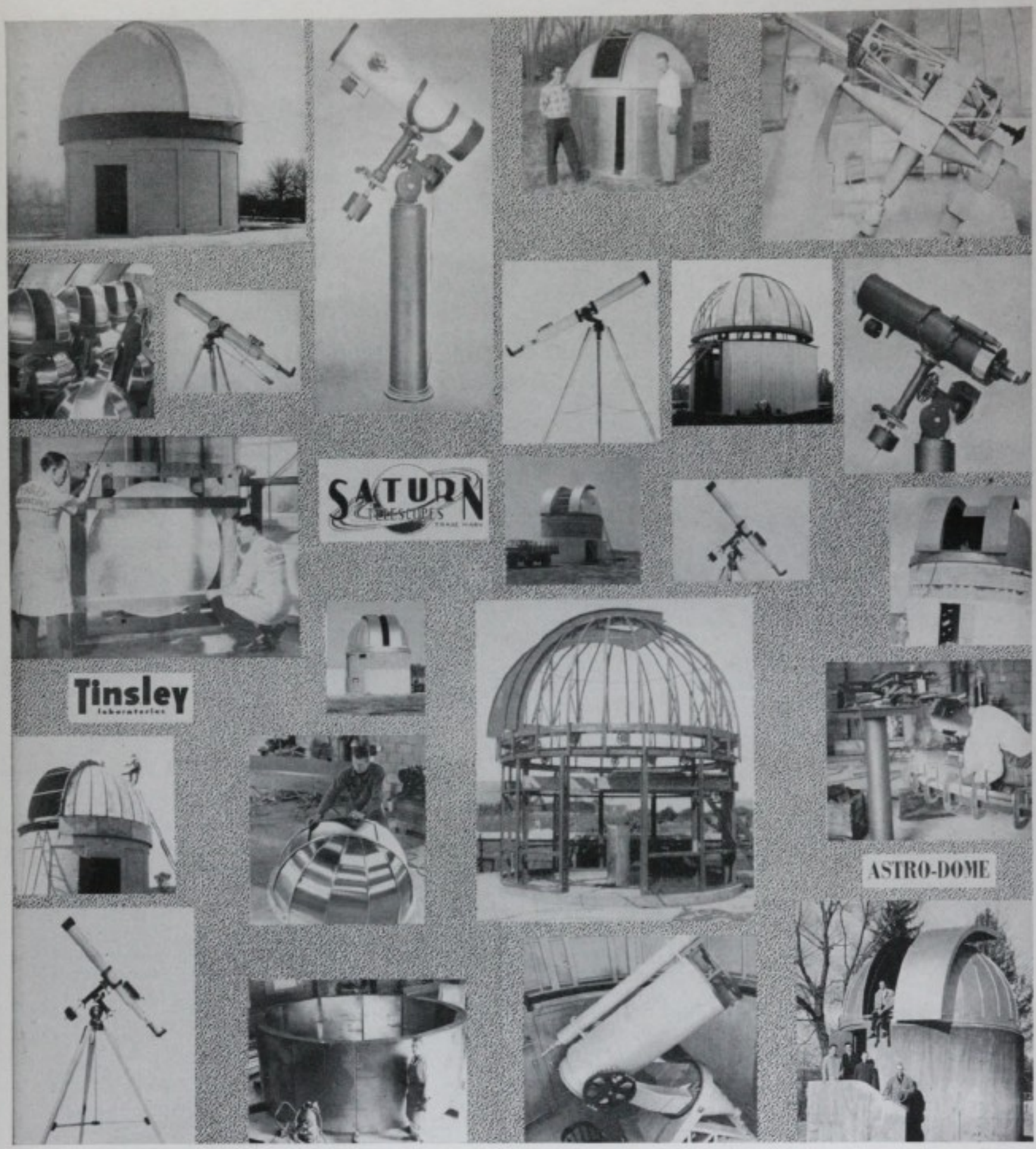

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Mr. Arber used his 6" UNITRON to take the photograph of the transit of Mercury that appeared on page 447 of the July, 1957, issue of "Sky and Telescope." His photographs of the solar eclipse, shown on pages 450 and 451 of the September, 1955, issue, were taken with his UNITRON 4" Model 166.

See pages 552 and 553.

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